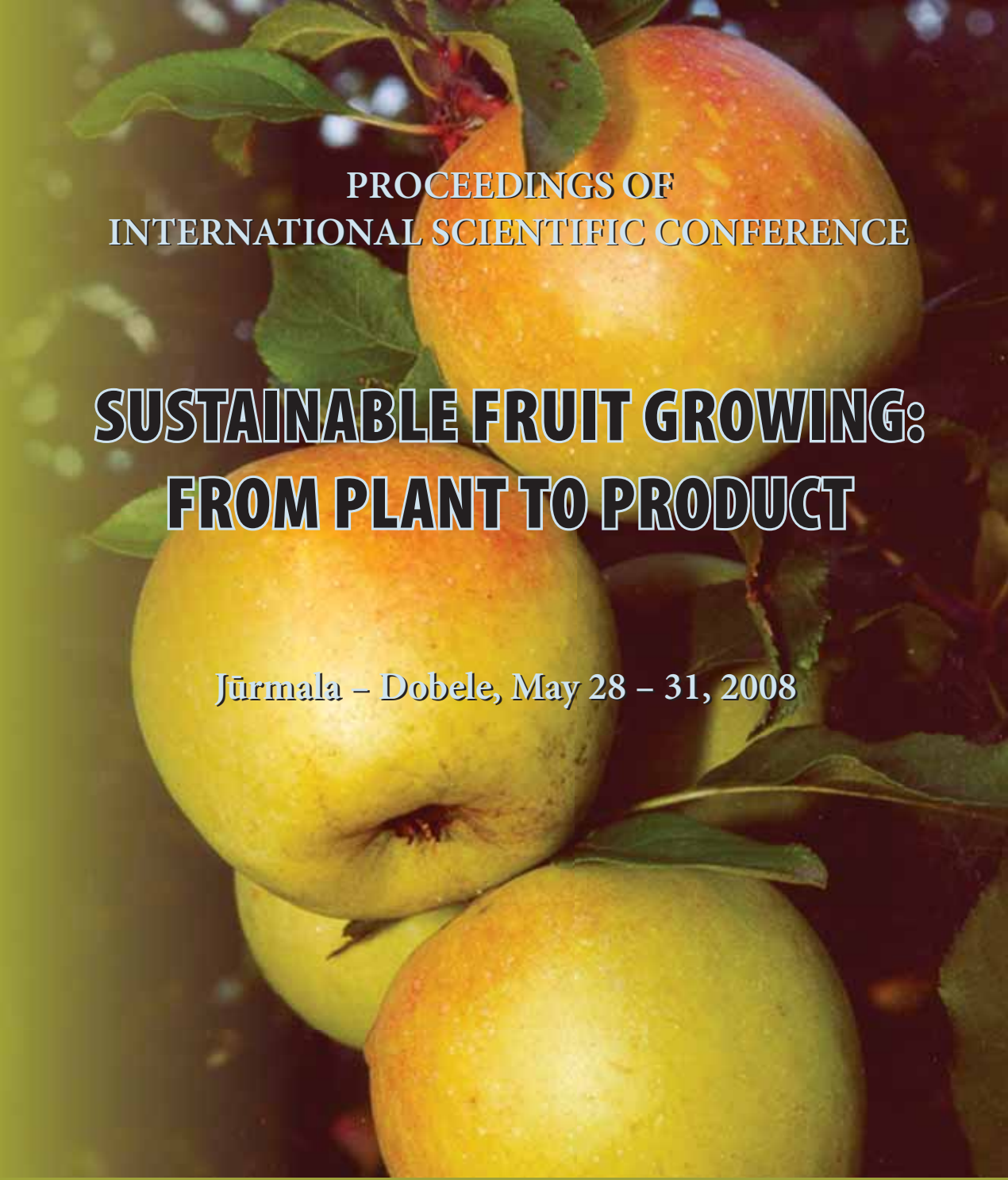

PROCEEDINGS OF
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SUSTAINABLE FRUIT GROWING: FROM PLANT TO PRODUCT

Jūrmala – Dobele, May 28 – 31, 2008

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Publisher:

Latvia State Institute of Fruit-Growing
Graudu str. 1, Dobele, LV 3701
Phone: + 371 63722294
Fax: + 371 63781718
e-mail: lvai@lvai.lv
website: www.lvai.lv

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CONTENTS

FRUIT AND BERRY GROWING IN LATVIA

Māra SKRĪVELE, Edīte KAUFMANE, Sarmīte STRAUTIŅA, Laila IKASE, Silvija RUISA, Edgars RUBAUSKIS, Māris BLUKMANIS, Dalija SEGLIŅA

Latvia State Institute of Fruit-Growing
Graudu 1, Dobele, LV 3701, LATVIA
e-mail: kaufmane@latnet.lv

Abstract

Fruit and berry growing has old traditions in Latvia, and the climatic conditions and soil are favourable for it.

Successful development started in fruit growing before the 2nd World War. After the renewal of independence of Latvia in 1991, as a result of the agricultural reform, many farmers have recognized fruit growing as one of the ways of successful investment. Since subsidies are paid for the establishment of orchards, the areas of fruit plantations are growing rapidly. Still a major part of orchards are home gardens, and the significant amount fruits and berries produced there is not sufficiently accounted for in statistics.

Apples are by far the most widely grown fruit crop in all types of orchards, about 9 000 ha. Yet only 1 300 ha of these are commercial orchards (larger than 1 ha and planted with the aim to produce fruits for market). The largest part of commercial orchards: 76.8% were planted in the last 9 years. The number of apple varieties grown is too big for the needs of supermarkets, the 10 most popular cultivars make only 45.7% of plantation area. The most widely grown are 'Antonovka' (in older orchards), 'Auksis', 'Sinap Orlovskii' and 'Antei'. As a large part of the plantations are still young, the average yield per hectare is not high, yet the average yields obtained at research institutions and the best farms – 30-40 t/ha – demonstrate that with improved orchard management such yields can be obtained in most orchards. Fruit storage still uses mostly traditional cool storage; research has only started to promote implementation of modern storage technologies.

The areas of black currants, red and white currants, raspberries and strawberries also have rapidly increased during the last 10 years. As technologies reducing risks (irrigation, protection against frosts, various top covers) are not widely used, the average yields are low and unstable. There are still problems in the harvesting, freezing and processing of berries, therefore during the last years the number of berry growers has reduced. At the same time, these problems have been successfully solved in many farms.

The proportion of other fruit crops, which present more risks in production and which have few well-adapted cultivars with good fruit quality, is low. Pears, plums and cherries make only 13% of the total orchard area.

Relatively stable yields are obtained in the growing of crops which are well-adapted to Latvian climate, but so far less known – seabuckthorn and large-fruited cranberries. Their total areas are still small, but show stable increase. There are also successful solutions in the harvesting and processing of the produce. The current experience shows that, as long as risk-reducing technologies are not introduced into the cultivation of highbush blueberries, the growing of this crop can be economically risky.

The farm size is different – small farms with orchard area 1 to 3 hectares dominate, they form about 40% of total orchard area. About 50% of the area make farms with 3 to 15 ha orchards, and only 6% are larger farms over 15 hectares. Insufficient cooperation is an obstacle to faster development of fruit growing, although there are some cooperatives formed. Specialized farms

dominate – 38% of farms are growing only one species, and 34% of farms grow 2 or 3 fruit or berry species. Integrated growing system was introduced in most farms since 2006.

Key words: apples, pears, plums, cherries, currants, raspberries, strawberries, seabuckthorn, cranberries, blueberries, growing area, farm size, specialization

Introduction

Fruit growing has old traditions in Latvia, and the climatic conditions and soil are favorable for it, especially in the eastern regions of Latvia. Latvian fruits and berries may contain somewhat less sugar than the cultivars grown in the south, yet they have more aroma and organic acids, and significantly less pesticide sprayings are needed for their growing.

Climate of Latvia

The climate of the western part of Latvia is maritime, but continental climate prevails in the eastern part. The cyclone activity is high (120 – 140 cyclones per year), and so the weather is very changeable. Precipitation (rainfall and snow) is 560 – 850 mm. The yearly average temperature is 6.6 (maritime) to 4.2 °C (continental). Monthly average temperature is about -2.6 to -7.5 °C in January and +16.8 to +17.6 °C in July. The lowest temperature recorded is -43.2 °C, the maximum is +36.4 °C. One of the biggest problems for successful fruit growing is frequent temperature fluctuations during the winter period from January to March. The growth season (t° over + 5 °C) is 180 – 200 days. Active growth season (t° over + 10 °C) is 135 – 140 days. Average temperature sum in active growth season: 1700 – 2150 °C, depending on region.

Relief and Soil

Lowlands are prevailing mostly in central part, in other regions they are separated by hilly uplands.

Soil is very variable. The most productive soddy calcerous soils, predominantly loams and drained soddy clay are found in southern Latvia.

The other parts of Latvia are mostly covered by more humid acid soils, podzolic, podzol and gley.

History of fruit and berry growing in Latvia

Before the 2nd World War, successful development began in fruit growing: fruit and berry export was started.

After the war in the time of the Soviet Union this process was interrupted by collectivization and nationalization of farms. Large extensive orchards were planted for the needs of the processing industry, so the areas of orchards and brutto yield increased rapidly at first. This process was sped up by the fast growth in the numbers of home garden owners. Yet the quality of production was lacking.

After the renewal of independence of Latvia in 1991, when the agricultural reform was started, many large-sized orchards were split up and returned to the previous landowners. A large number of rather small (10 to 20 hectares) farms were formed as a

result of the agricultural reform. Many have already recognized horticulture as one of the ways of successful development. The importance of home gardening is decreasing. In fresh berry market, commercial production is already dominating, while commercial production of pome and stone fruits still cannot meet the demand.

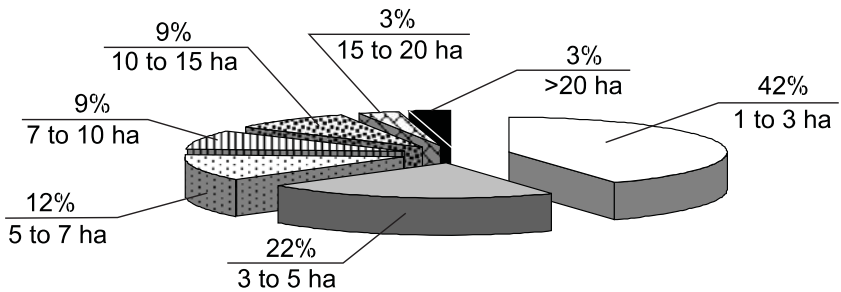

Figure 1. Breakdown of farms by orchard area

At present, small orchards (1 to 3 ha) are dominating (Figure 1). Only 6 % are larger than 15 ha, and almost all of these are relatively old orchards of former collective farms.

Since 1998, when subsidy payment started for orchard establishment, the areas increased by 2650 ha. Apples and black currants were the most planted crops (Figure 2).

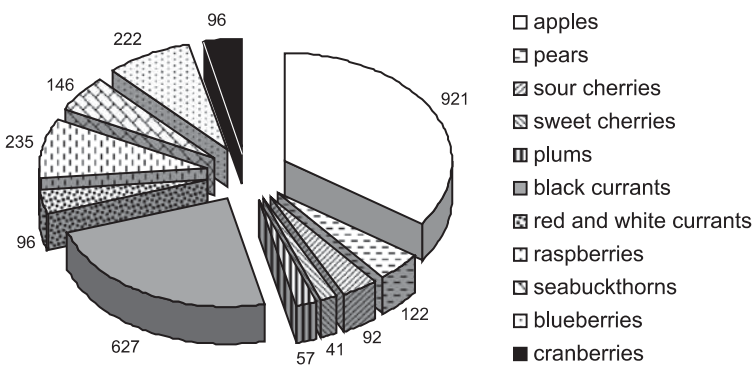

Figure 2. The area of planted orchards (1998 – 2006), ha

Apples

Apples are by far the most widely grown fruit crop in all types of orchards, about 9000 ha. Yet only 1300 ha of these are commercial orchards (larger than 1 ha and planted with the aim to produce fruits for market). The largest part of commercial orchards: 76.8% (920 ha) were planted in the last 9 years.

Fruit storage still uses mostly traditional cool storage; research has only started to promote implementation of modern storage technologies.

According to statistics, about 30 – 40 thousand tons of apples are produced annually in Latvia, of which so far only a part are harvested in commercial orchards (Figure 3).

The amount of apple import during the last 10 years has decreased about 2 times. As the diversity of fruits in the market, especially imported, is increasing, the share of apples has reduced from about 60 thousand tons to 45 thousand tons. Apple consumption per head in Latvia is 15 kg. Data show that the consumers prefer locally grown apples. If the yield in Latvia is low, import still does not increase.

Latvians prefer to have a wide range of varieties. In fruit growing the 10 most popular cultivars make only 45.7% of plantation area (Figure 4). The most widely grown old cultivar is 'Antonovka', which is used mostly for processing. It is recommended for growing only in the eastern regions of Latvia, where it has good quality of fruits. The assortment in commercial growing has not yet fully established. In the new commercial orchards cultivars suitable for dessert and/or long storage are dominating – 'Auksis' (the most popular), 'Sinap Orlovskii', 'Antei', 'Belorusskoe Malinovoe', 'Lobo', 'Rubin' (Kazakhstan cv.), 'Kovalenkovskoe', 'Saltanat', 'Zarya Alatau'. Cultivars of Latvian breeding are also planted in new orchards – 'Iedzenu', 'Forele', 'Ilga', 'Alro'.

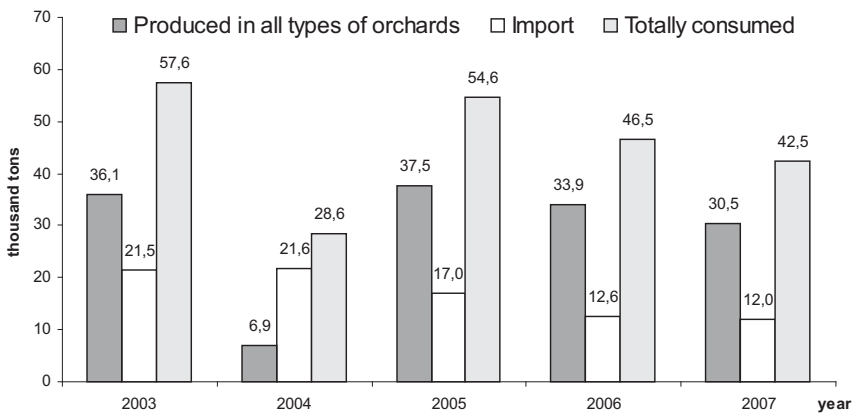

Figure 3. Amount of produced, imported and consumed apples, thousand tons

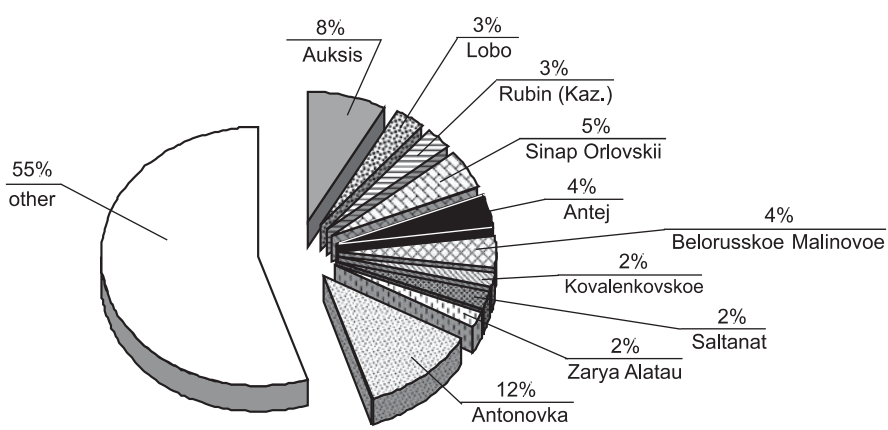

Figure 4. The structure of apple cultivar areas, %

To avoid fungal infection and lack of available sunshine, high density and double-row plantings are not recommended in Latvia. The recommended rootstocks for apple are: MM 106, B 118 (semi-dwarf), B 9, B 396 (dwarf) (Figure 5). Trials have been established for clonal rootstocks from Poland, USA and Canada. A new rootstock Pure-1 has been selected in Latvia.

Main problems in apple production:

As a large part of the plantations are still young, the average yield per hectare is not high, yet the average yields obtained at research institutions and the best farms – 30-40 t/ha – demonstrate that with improved orchard management such yields can be obtained in most orchards.

The high share of home gardens makes the market unstable and unpredictable. This hinders the development of processing using Latvian-grown fruits, too, as apples for processing are mostly supplied by old orchards and home plots. No system of fruit storage and marketing has been developed yet.

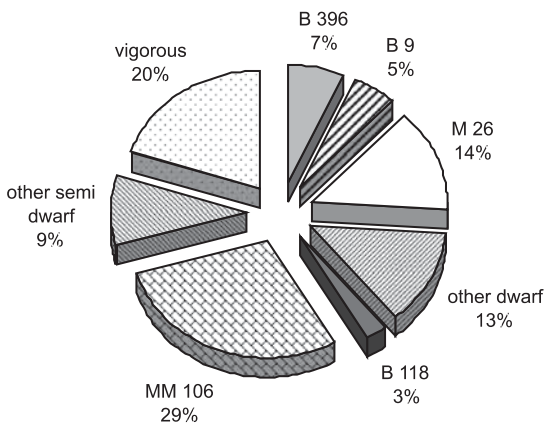

Figure 5. Most widely used apple rootstocks in Latvia

Pears

The commercial pear plantations in Latvia are small, only 200 ha, of these 122 ha were planted during last 9 years using subsidies for orchard establishment.

The most popular cultivars are 'Belorusskaya Pozdnaya' (leading cv.), 'Suvenirs', 'Vasarine Sviestine', 'Pepi', 'Mramornaya', 'Moskovskaya' and 'Kurzemes Sviesta' (Figure 6). About 34 pear cultivars are grown in commercial orchards and, similar to apple orchards, the 7 more popular make up 59 % of the area.

Main problems in pear production:

- Lack of hardy cultivars with high fruit quality and storage potential;
- Choice of suitable rootstocks and hardy frame-builders which is very important for this crop;
- Winter-hardy frame-builders which are a way of growing more tender high quality varieties;
- During last years, pear-juniper rust is dangerously spreading in part of plantations.

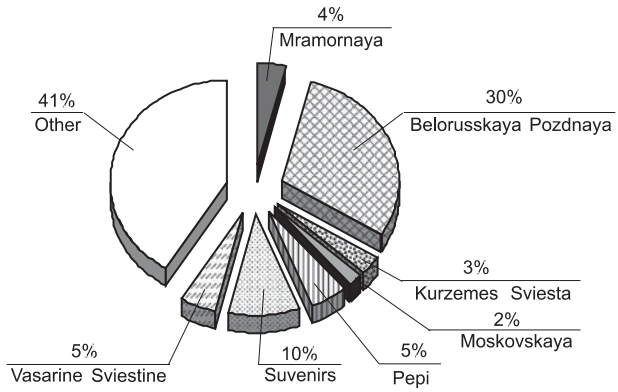

Figure 6. The structure of pear cultivar areas, %

Cherries

The total area of cherry plantations is about 890 ha, of these 90 ha of sour and 41 ha of sweet cherries have been planted for market production, using subsidies for orchard establishment.

At present, only one **sour cherry** cultivar is being widely grown in Latvia – the local cultivar 'Latvijas Zemais'. Better sour cherry cultivars with more firm fruit flesh and small stone are lacking. Sour cherry plantations are established with micropropagated plants, as well as trees budded on *Prunus mahaleb* seedlings and plants from self-rooted layers.

The growers have some interest also in the planting of **sweet cherry**. The assortment is formed by Russian cultivars – 'Iputj', 'Bryanskaya Rozovaya' and the Estonian 'Meelika'. The local cherries can not compete with the imported fruits in size, yet the consumers value them for their good flavour. As there is a lack of winter-hardy cultivars with high quality fruits, some work has been done in sweet cherry breeding.

Sweet cherries at present are grown on *P. mahaleb* and *P. avium* seedling rootstocks.

Serious damage during the last years is caused by cherry fly.

Plums

The total area of plum plantations is 980 ha, of these 57 ha have been planted for commercial production using subsidies for orchard establishment.

So far, *Prunus cerasifera* seedlings are being used as rootstocks for plums.

Plums are grown mostly for the fresh market, and for this reason the plantations are established with a number of cultivars ripening along an extended period of time, to supply the market as long as possible. The area of 6 most popular plum cultivars is 69 % of the total area. An extremely early maturing diploid cultivar is 'Kometa'. For commercial orchards, recommended cultivars are also 'Victoria', 'Julius', 'Experimentalfältets', 'Perdrigon', 'Stanley' and 'Lase'. Recently, the Eurasia group of plums has acquired interest. This group is represented by cultivars 'Aleynaya', 'Zarechnaya Rannaya' etc. Still, there is a lack of winter-hardy cultivars with high fruit quality.

Strawberries

The area of strawberry plantations is about 550 ha. Strawberries are grown mostly for the fresh market. The most important cultivars for commercial growing are 'Zefyr', 'Induka', 'Korona', 'Dukat', 'Siurprise Olimpiade', 'Jonsok', 'Bounty', 'Senga Sengana', 'Polka' .

Most of strawberry plantations are grown without moisture regulation systems.

The reasons for low yields are:

- low quality of planting material;
- low level of growing technologies.

Strawberry production has decreased during the last years (Figure 7). The reason is lack both of work-hands and risk-reducing technologies. As result, the number of strawberry growers has stabilized, but the consumption has reduced because of high prices.

For processing purposes most berries are imported, because freezing of strawberries is still a problem in Latvia.

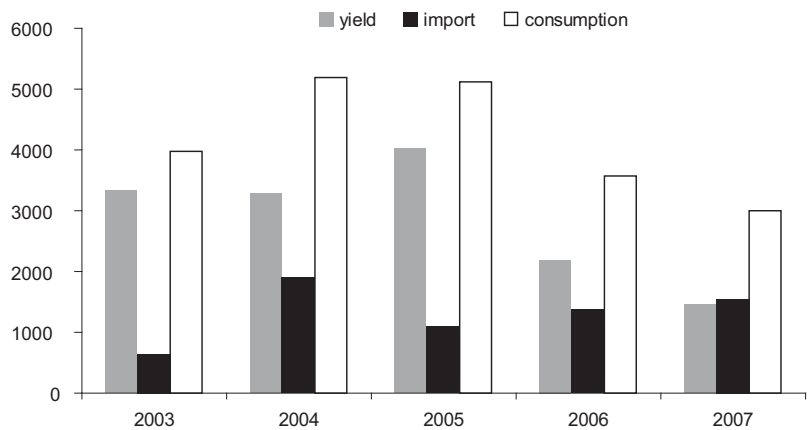

Figure 7. Strawberry market in Latvia, tons

Black currants

The area of commercial plantations of black currants has reached 700 ha, the average yield is 4.4 t/ha. The most important cultivars for commercial growing are: 'Zagadka', 'Pamyati Vavilova', 'Katyusha', 'Mara', 'Ben Lomond', 'Titania', 'Triton', 'Ojebyn'. For mechanical harvest the best cultivars are 'Katyusha', 'Mara', 'Ojebyn'.

The reasons which prevented more rapid development of black currant production:

- lack of cultivars with high level of winter hardiness and spring frost resistance, disease resistance (reversion virus) and gall mite resistance;
- small area of individual plantations and low level of cooperation between growers, harvesting mechanization;
- low level of growing technologies.

Red and white currants

The area of plantations is 93 ha. Average yield is 4 t/ha. Red and white currants are mostly grown only for processing. Growing for fresh market is not popular in Latvia. The problems are similar as for black currants. Most widely grown cultivars are 'Red Dutch', 'Jonkheer van Tets', 'Zitavia', 'Werdavia', 'Rondom', 'Vīksnes Sarkanās'.

Gooseberries

Gooseberries are less important for commercial growing. Only a few hectares were planted during 1998 – 2006. Gooseberries are mostly grown for fresh market.

The most important cultivars are: 'Lepaan Valio', 'Lepaan Punainen', 'Kuršu Dzintars', 'Koknese', 'Pērse', 'Veldze', 'Masheka', 'Tukuma Konfekšu'.

The problems in gooseberry growing are: fruit harvesting and lack of cultivars with big fruits (6 and more grams).

Raspberries

The area of raspberry plantations in 2007 reached 235 ha. Average yield is 3 t/ha.

Most grown cultivars are: 'Lazarevskaya', 'Norna', 'Ottawa', 'Skromnitsa', 'Meteor', 'Tomo', 'Kirzach', 'Sputnitsa' and 'Polana'. For the improvement of the assortment the cultivars 'Ina', 'Lina', 'Arta', 'Dita' were bred at the Latvia State Institute of Fruit-Growing.

The most important problems: winter-hardiness of cultivars, disease resistance, yield, fruit quality, storage and quality of plant material, growing management, also – risk reducing technologies.

Highbush blueberries

Plantations of highbush blueberries at present are 222 ha, of which only about 10 ha have started production. The fruits are sold mostly for fresh consumption. As this crop is very new in Latvia, there is a lack of experience in variety choice and soil management. Because of high costs, risk-reducing technologies have not yet been introduced in the plantations.

The most important cultivars are: 'Blue Ray', 'Patriot', 'Duke', 'Bluecrop'.

Cranberries

Several larger, modern commercial cranberry plantations have been established. Latvian climate is favourable not only for the European wild cranberry, but also for large-fruited American cranberry. All new plantations are established with large-fruited cultivars. Latvia has enough bogs and acid soils which are necessary for this crop. The area of plantations is 96 ha, of which only 45 ha have started production. The number of cranberry growing farms is 30, of these only 6 have plantations above 4 ha, but 11 farms have below 1 ha.

The local market may be filled with fresh berries and cranberry products during the next 10 years. Export both of fresh cranberries and processed products has already started.

The most important cultivars are: 'Ben Lear', 'Bergman', 'Early Black', 'Franklin', 'Stevens'.

Seabuckthorn

Recently sea buckthorns are planted widely, mostly Russian cultivars. Their area has reached 146 ha. Cultivars for commercial growing are: 'Botanicheskaya Lubitelskaya', 'Prozrachnaya', 'Avgustinka'. The diversifying of berry processing has been successful. Most of the production until now was exported, but at present sea buckthorns are processed in Latvia. The most important problem is harvesting, which is being successfully solved at present.

Japanese quince

In the 1980ies-1990ies the plantations of *Chaenomeles* (Japanese quince) increased rapidly. Yet, as good methods of commercial processing of this valuable crop were not found then, the area of plantations drastically decreased.

Today, when several interesting processing products have been worked out for *Chaenomeles*, interest in this crop is reborn.

First Latvian-bred cultivars for fruit production are prepared for registration at the moment.

Fruit and berry processing

The largest processing enterprises which use also Latvian-grown raw material make juices or juice concentrates, as well as additives to ice-cream and yoghurt.

The amount of apples sold for processing at present is decreasing, because in the modern intensive orchards it is more profitable to produce dessert fruits for which the market demand is still not met.

Joining the EU stimulated the establishing of small and home processing enterprises which process not only the traditional fruits and berries, but also new crops with high nutritive value – seabuckthorn, Japanese quince, cranberry.

At the moment there are about 30 such enterprises in Latvia, whose activities help to diversify the processed products in the market.

The main problems in the development of fruit growing are:

- Insufficient ties between the growers and the food processors, as well as between the growers and the market.
- Cooperatives are starting to develop, but slowly. Some food processing plants have agreements with local growers, but others are importing raw material.
- The quality of the product, especially of the pome and stone fruits, is not always high enough. To improve quality, horticultural knowledge in the field of high quality fruits must be widely spread. The varietal structure must be changed also.
- Lack of modern fruit storage and processing facilities.
- Risk-reducing growing technologies are not yet used.
- The diversity of available means for plant protection is limited because of the small market.

Fruit growing has high potential in Latvia:

1. Fruit growing has already taken a stable place in the agricultural production of Latvia.
2. In total 11 fruit crops are grown commercially, and their area has increased for 2650 ha during the last 10 years.
3. The production is diverse – fresh fruits and berries, various processed products. So in comparison with other spheres of agriculture fruit growing is less dependent on the large processing enterprises.
4. The income per ha is high (intensive orchards).
5. Original processed products have a wide perspective, developing processing at farms and small enterprises.
6. Market demand for local fruit production still is not satisfied.
7. Increasing consumer preference for locally grown fruits and their products.
8. All these factors work for the development of fruit growing in Latvia.

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Part A

"FRUIT AND BERRY BREEDING AND VARIETY TESTING FOR SUSTAINABLE PRODUCTION"

RESULTS OF SLOVAK APRICOT BREEDING PROGRAM FOR GROWING PRODUCTION

Daniela BENEDIKOVA

Slovak Agriculture Research Centre – Research Institute
of Plant Production Piestany, Slovak Republic,
e-mail: benedikova@vurv.sk

Abstract

Growing of apricot has a long tradition also in Slovakia regardless of fact that geographical and eco-climatic conditions make Slovakia the northern boundary of apricot production in Europe. The breeding program to obtain a genetic improvement of the apricot began in 1964 at the RIPP Piestany. This program has been carried out according to several objectives, most important were resistance to frost, high fruit quality and resistance to diseases.

Standard breeding techniques i.e. self pollination, open pollination, crossing by emasculation and hand pollination has been employed. The most interesting selections were grafted on the standard rootstocks and planted in trials so that it was possible to observe their behaviour compared with the control cultivar Hungarian Best. Nowadays program continues in hybridisation oriented mainly on fruit quality and resistance do diseases.

The main cultivars utilised as parent in the hybridisation program were European, central Asian and Chinese cultivars. During the period of breeding over 600 parent combinations were realised, and about 10 000 seedlings have been obtained. Since the start day of the breeding programme up to now, 10 cultivars have been registered in Slovak Republic. The new assortment has late blossoming, better quality of fruits and a prolonged maturation period of fruit, resistance to pathogens. The most perspective are ´Vesna´, Veselka´, 'Veharda' and 'Vemina'.

Registered cultivars and very perspective hybrids were included into collection of genetic resources of the National program. This program is coordinated by SARC-RIPP Piestany.

Key words: fruit quality, frost resistance, genetic resources, resistance to PPV

Introduction

Apricots are grown in temperate and subtropical zones world-wide being the third economically most important stone fruit crop after peach and plum. The main apricot growing areas are China, the Irano-Caucasian region, Central Asia, Europe and North America, which represent different eco-geographical groups.

By comparison with other fruit species, apricot cultivation is characterized by interesting prospects either from the economical point of view or on the impact of landscape management in fragile areas. But strongly related with a clear phylogenetic structure, the wide genetic variability appeared more as a default than as a quality able to be valorised: and, as for most of fruit species, a serious concern exists with the enlargement of pest and diseases pressure and with the required anticipation to face the problems (Bassi and Audergon, 2006).

In this context most of the countries developed applied research programmes to face punctual problems to be solved such as the enlargement of the period of production, the regularity of the production, the training of the orchard or the follow-up of the

production after picking and the protection against bio aggressors. Breeding programs of apricot have long tradition in Europe and have achieved many very interesting results in particular countries (Egea, Dicenta, Burgos, 2006; Pennone, Abbate, 2006; Karayiannis, Mainou, 2001; Bassi, Audergon, 2006).

Growing of apricot has a long tradition also in Slovakia regardless of fact that geographical and eco-climatic conditions make Slovakia the northern boundary of apricot production in Europe. In these conditions apricot orchards have limited longevity, flower buds are frequently injured during winter and spring by frost. It is evident that apricot is a "risk" species for Slovak farmers.

Breeders have tried to overcome some of above mentioned factors in a long-termed program of hybridisation. The low geographic plasticity of the apricot species means that a breeding program is necessary to generate cultivars which are adapted to the specific condition of Slovak production area (Benedikova, 2006, 2008; Jakabova, 2007).

The Central-Asian group is the oldest group with the richest variation. Most of the cultivars are self-incompatible; fruits are small to medium and ripen over a long period. The Iran-Caucasian group is mostly self-incompatible, produces larger fruit than the Central Asian group and shows lower chilling requirements. The European and the North American groups are the youngest with the lowest variation, probably originating from a few Asian ancestors (Zohary, Spiegel Roy, 1975). Domestication of this fruit tree led to a decrease in variability in the European cultivars, which are mostly self–compatible, show lower chilling requirements and only a short ripening time (Mehlenbacher et al., 1991).

Material and methods

The apricot breeding program of Slovakia was initiated in 1964 at the Fruit Tree Department RIPP Piestany, later continued on the Research Breeding Station Vesele. Principal breeding aimed at the development of late flowering apricot types with resistance to spring frost. High quality, early and late ripening and resistance to diseases were very important, in addition. Standard breeding techniques i.e. self pollination, open pollination, crossing by emasculation and hand pollination have been employed. During the period of breeding over 600 parent combinations were realised and about 10 000 seedlings have been obtained. The most interesting selections were grafted on the standard rootstocks M-VA-2 (apricot seedling) and planted in trials so that it was possible to observe their behaviour compared with the control cultivar Hungarian Best. Description of hybrids and later cultivars was done under the IPGRI Descriptor list (Guerriero, Watkins, 1984). Nowadays apricot selection program continues in hybridisation oriented mainly on fruit quality and resistance do diseases (PPV, *Monilinia sp, Gnomonia erythrostoma).*

Results and Discussion

History of breeding program

I. period 1964-1975 – first hybridisation with mother cultivars like: ´Hungarian Best´, ´Ananas´, ´Rakovskeho´, ´ Urozajnyj´, ´Julskij' and local types of apricots. Like father cultivars were used ´Achrori´, ´ Arzami´, ´Zard´, ´Hindukush´ and Chinese white and yellow flesh types.

II. period 1976-1987- hybridisation between promising hybrids and back-crossing. In this period hybridisation started between perspective cultivars from the collection of genetic resources. Mother cultivars were central Asian hybrids, Chinese hybrids VS 27/8, VS 9/83, VS 51/4, VS 25/38, VS 74/14, VS 09/12, and ´Veecot´, ´Sunglo´, ´Goldcot´,´ 'Kesh Pchar´, ´Marculesti 19´ and ´Hungarian Best´. As father cultivars breeders used mainly ´Goldcot´, NJA 44, ´Sunglo´,´Tirziu de Bucuresti´ and others.

III. period 1988-2006 – hybridisation of promising hybrids, hybridisation in the frame of germplasm collection and hybridisation oriented on the resistance to important diseases.

Mother cultivars were ´Vesna´, ´Vegama´, ´Veharda´, ´Velbora´ and hybrids like VS74/14, VS9/83, VS51/4, VS023/51, VS67/84, which were later registered as Slovak cultivars. As father cultivars were used ´Goldcot´, ´Goldrich´, ´Stark Early Orange´, ´Henderson´, ´Harlayne´,´Stela´, ´Screara´ and hybrids NJA 77, NJA 78, NJA 35.

Donors of properties

Cultivars most often used in the breeding program as donors of properties were:

- disease resistance ('SEO', 'Dacia', and Chinese local types);
- frost tolerance (the central Asian cultivars 'Achrori', 'Arzami', 'Zard');
- extended blossoming period ('Ananasova');
- extended ripening period ('Ruzova skora', 'Kech Pchar', 'Vynoslivyj', NJA hybrids) fruit quality ('Hungarian Best', 'Bergeron', 'Hargrand', Chinese local types;
- self-fertility.

Evaluation of basic parent cultivars

´Hungarian Best´

Very good for hybridisation, it gives to progeny important characters like size and taste of fruit, self fertility. Hybrid had no higher frost tolerance than original cultivars.

´Hindukush´

Local genotype, originates from Hindukush Mountains. Mostly used like father in breeding combination, with important expression of characters in progeny. Fruit have small size, later date of ripening, mealy consistency of flesh, high frost tolerance, good health status of trees.

Chinese local genotypes

Genotypes were used in mixture of pollen (yellow and orange flesh). In the F1 progeny expressively influenced good size of fruit, colour of flesh (white, dark yellow), tolerance to fungal diseases. Trees have limited longevity, health status of skeletal branches was worse. Flesh has high content of sugar, some hybrids were clingstones.

´Julskij´

When used like mother the result was worse. In progeny undesirable characters like small size of fruits, worse taste, fibrous flesh, susceptibility to fungi pathogens. Progeny has later time of blooming and high resistance to frost.

Evaluation of parent combinations

Two groups of original cultivars were important for apricot breeding program in Slovakia: Central Asian and European group. Another geographically distant type was used from China and from the Hindukush mountains. Improving of selected genotypes and back-crossing has been done in the second and third period.

´Hungarian Best´ x mixture of Chinese local types

Characters obtained in F1 generation were large fruit size, intensive dark orange colour of flesh, high content of sugar, worse separation of stone, very good healthy status of leaves and worse status of skeletal branches and limited longevity of trees.

´Julskij´ x ´Hungarian Best´

Character in F1 generation: high frost tolerance of flower buds and small fruits, late ripening, small size of fruit with pale orange colour of skin, worse taste of fruits.

´Hungarian Best´ x ´Achrori´, ´Arzami´, ´Zard´

Characters in Fl generation: good quality of fruits, white to pale orange colour of flesh, excellent health status of trees, no attack of fungi diseases, very healthy stem of trees, partial self sterility of hybrids.

The most perspective cultivars from the last period of the breeding program

´Veselka´®

Origin: ´Vesna´ x ´Vegama´.

Fruit: ripening very early (10 July), very large fruit, weight 65 g, shape spherical, firm fruit, good transportability, skin dark orange with attractive dark red face, flesh light orange, flavour very good.

General evaluation: Dessert cultivar, very early ripening, spur type growth, attractive large fruit, and very good flavour. Good level of resistance to *Gnomonia erythrostoma*.

´Velita´®

Origin: ´Hungarian Best´ x 'Achrori', 'Arzami', 'Zard' (Central Asian cultivars).

Fruit: ripening very early (7 July), large fruit, weight 56 g. Shape flat elongate, skin light orange with dark red face, firm flesh and light orange, good flavour, harmonic.

General evaluation: Very early cultivar with large attractive fruit and regular yields.

´Vemina´®

Origin: ´Rakovsky´ x 'Achrori', 'Arzami', 'Zard' (Central Asian cultivars).

Fruit : ripening late (27 July), large fruit, weight 50 g, shape spherical, very firm fruit, very good transportability, skin dark orange with attractive dark red face, high shine, flesh dark orange, flavour good, aromatic.

General evaluation: Universal apricot cultivar, mainly for processing, attractive appearance of fruit, very good flavour, resistance to PPV – M.

´Vestar´®

Origin: ´Hungarian Best´ x China landraces.

Fruit: ripening end of July, very large fruit, weight 55 g, shape circular, colour of skin dark orange with attractive red face, flesh dark orange, flavour very good, harmonic.

General evaluation: Attractive dessert cultivar with low density of crown and very good transportability of fruits.

Conclusions

During the period of breeding over 600 parent combinations were realised, about 10 000 seedlings have been obtained in orchards. Since the start breeding programme in 1964 up to now 10 cultivars have been registered in Slovakia. There are ´Vesna´, ´Vegama´, ´Veharda´, ´Velbora´, ´Vemina´, ´Velita´, ´Vesprima´, ´Barbora´, ´Vestar´, ´Veselka´. The new assortment has late blossoming, better quality of fruits and a prolonged maturation period of fruit.

Frost hardiness was achieved through later beginning of flowering (´Veharda´) or through prolongation of blossoming with gradual blooming (´Vegama´). Resistance to PPV M strain (´Veharda´, ´Vemina´), high fruit quality (´Vesna´, ´Vestar´, ´Veselka´) fruit transportability (´Veharda´, ´Vemina´) were achieved.

Our results confirmed that cultivars from the Asian group were the source of higher frost hardiness in the breeding program, but at the same time their progeny had small size of fruits and lower flesh quality and self-incompatibility.

The progeny of the local Chinese cultivars had attractive appearance with red face, dark orange colour of flesh, high content of sugar, but shorter tree longevity.

The progeny of the European group had the higher quality of fruits, orange colour of flesh but lower resistance to frost.

All Slovak origin cultivars were included into the new collection of apricot genetic resources. This collection was founded as a field collection of Gene bank SR in SARC-RIPP Piestany three years ago.

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Table 1. Slovak apricot cultivars

Hybridi-sation	Registra-tion	Cultivar	Blooming time	Ripening time	Fruit characteristics		
					mass g	category	flesh colour
1964	1991	VESNA	VE	17.7. E	55	AAA	Y
1979	1999	VESELKA	VE	10.7. E	62	AAA	DO
1963	1991	VELBORA	M	30.7. M	58	AAA	O
1972	1997	BARBORA	M	1.8. M	56	AAA	O
1970	1997	VESTAR	E	1.8. M	55	AAA	O
1972	1996	VESPRIMA	L	4.8. M	55	AA	DO
1968	1991	VEGAMA	L	12.8. L	49	AA	DO
1964	1991	VEHARDA	VL	7.8. L	50	AA	O
1964	1999	VEMINA	E	14.7. E	50	A	O
1972	1999	VELITA	E	7.7. VE	56	A	Y
Control cultivar		Hungarian best	E	30.7. M	51	AA	O

Notes:

Blooming and ripening time:
VE – very early
E – early
M – midle
L – late
VL – very late

Flesh color:
Y – yellow
O – orange
DO – dark orange

Fruit size category:
A – 45 mm diameter
AA – 50 mm
AAA – 55 mm

PRELIMINARY EVALUATION OF 'ELISE' APPLE TREES ON FIVE ROOTSTOCKS IN A YOUNG ORCHARD

Pawel BIELICKI, Alojzy CZYNCZYK, B.BARTOSIEWICZ

Research Institute of Pomology and Floriculture, 96-100 Skierniewice, Poland
e-mail: pbielick@insad.pl

Abstract

The field experiment was established in the spring of 2003 in the Experimental Orchard in Dabrowice, near Skierniewice, on a sandy loam podsolic soil underlaid by loam. The influence of five dwarfing apple rootstocks on tree growth, yield and fruit quality of the cultivar 'Elise' was studied. Two-year-old trees with a one-year-old crown ("knipboom"), grafted on rootstocks M.9, P 60, M.26, P 14 and M.7, were planted at the same spacing of 4.0 x 2.0 m (1250 trees/ha). After the first five years of the experiment, the M.9 rootstock induced the slowest growth in 'Elise' trees. The size of the trees on that rootstock was the smallest. Among the semi-dwarfing rootstocks, the trees on P 60 were smaller than the trees on the standard rootstock M.26. The P 60 rootstock reduced tree growth to the same extent as M.9 The vigour of the trees on P 14 was similar to that of the trees on the standard M.26 rootstock. The most vigorously growing trees were obtained on the P 14 rootstock.

The trees of the cultivar 'Elise' began to bear fruit in the second year after planting. The highest cumulative yield (2004-2007) was recorded for trees on M.26. The trees grafted on M.9 produced the lowest yields. In 2007, the fruit quality parameters (size, mean mass, and fruit colour) of 'Elise' apples were generally very good on all rootstocks.

Key words: apple, clonal rootstock, fruit quality, growth, *Malus sp*., yield, yield efficiency

Introduction

In order to establish intensive orchards on lighter soils, trees grafted on semi-dwarfing rootstocks are required (Mika, 1994). Polish soil and climatic conditions are less suitable for growing fruit trees than those in Western Europe. On light soils, which are predominant in Poland, trees on M.26, P 14 and P 60 are more suitable for fruit growing than trees on dwarfing rootstocks. Only for more fertile soils with balanced water ratios, and for irrigated systems, trees on very dwarfing and dwarfing rootstocks are recommended (Mika, 1992). According to Ystaas (1997) and Wertheim (1998), the rootstock is one of the main factors in intensive orchard design. The choice of rootstock affects the apple tree in many ways: tree vigour, tree size, precocity, yield, yield efficiency, fruit size, fruit quality, anchorage in the soil and winter hardiness.

The aim of the experiment was to determine the usefulness of dwarfing and semi-dwarfing rootstocks for growing 'Elise' apple trees. An evaluation of five rootstocks with obvious differences in growth vigour should accurately single out the best rootstocks for the production of trees of this cultivar in the soil conditions of central Poland.

Material and methods

The field experiment was established in the spring of 2003 in the Experimental Orchard in Dabrowice, near Skierniewice (central Poland), on a sandy loam podsolic soil

underlaid by loam. The influence of five dwarfing and semi-dwarfing apple rootstocks on tree growth, yield and fruit quality of the cultivar 'Elise' was studied. Two-year-old trees with a one-year-old crown ("knipboom") grafted on rootstocks M.9, P 60, M.26, P 14 and M.7 were planted at the same spacing of 4.0 x 2.0 m (1250 trees/ha). Trees grafted on M.9 and M.26 were used as standards. The experiment was set up in four randomized blocks with three trees per plot. Thus, there were 12 trees of the cultivar 'Elise' growing on each rootstock.

All the trees were trained as slender spindles and tied to a supporting structure. Herbicides were used to control weeds in the tree rows, whereas the inter-rows were grassed over in the second year after planting. Fertilization, plant protection and other agro-technical treatments were applied according to the standard recommendations for commercial apple orchards in Poland. The trees were drip-irrigated from the first year after planting.

In the course of the experiment the following observations and measurements were recorded: the health status of the trees, trunk circumference (measured at 30 cm above ground level), yield (determined every year, separately for each tree) and fruit quality (samples were taken from each replication). In 2007, fruit quality was assessed using an electronic sorting machine manufactured by Greef. Statistical analyses involved variance analyses and Duncan's multiple range test at P=0.05.

Results and discussion

Tree growth. After the first five years of the experiment, the M.9 rootstock induced the slowest growth in 'Elise' trees. The size of the trees on that rootstock was the smallest. Among the semi-dwarfing rootstocks, the trees on P 60 were smaller than the trees on the standard rootstock M.26. But the size of the trees on P 60 rootstock was only slightly bigger than of those on the standard M.9. Similar results were obtained by Bielicki et al. (2006) for P 60 with 'Celeste' trees grafted on it. In contrast, trees on P 14 were bigger than those on the standard rootstock. The results confirmed earlier reports by Czynczyk (1995), Jakubowski and Zagaja (2000) and Czynczyk et al. (2004) which stated that the Polish P 14 rootstock showed a weaker effect in reducing vigour than M.26. M.7 appeared to be a more dwarfing rootstock than P 14. This corresponded with the results obtained for 'Idared' trees by Hrotko and Berczi (1999) and for 'Elise' trees by Słowiński (2004).

Yield and Fruit Quality. The first yields from the cultivar 'Elise' were obtained in 2004 – the second year after planting (Table 1). The yields (about 2kg per tree) were similar from all the trees grafted on all five rootstocks. In the third year, the trees on all those rootstocks produced smaller yields. The yield obtained from the trees on M.9 was the smallest, only 0.3 kg per tree. Good yielding of 'Elise' on all the rootstocks was observed in 2006. The trees on all five rootstocks gave higher yields. There were no significant differences in fruit yield among the semi-dwarfing rootstocks. In 2007, the yields obtained from all 'Elise' trees were very small. This was caused by spring frosts, which had occurred during blooming time in the last days of April and first days of May, and damaged a lot of blossoms.

The highest cumulative yield (2004-2007) was recorded for the 'Elise' trees on M.26. Trees grafted on P 60, P 14 and M.7 showed lower but similar yields. However,

there were no significant differences in the total yield among the trees on all the semi-dwarfing rootstocks. The lowest yield was obtained from the trees on M.9. It was similar to those presented by Bielicki et al. (2006).

Tree productivity, expressed as the yield efficiency index, showed that the trees on all the rootstocks with the exception of the trees grafted on P 14, were productive on the same level. They had the highest yield efficiency index (expressed as a ratio of yield per tree to the trunk cross-sectional area [kg/cm^2]). The trees on P 14 had the lowest yield efficiency index.

In 2007, the size and mass of apples and the percentage of apples having more than 50% of their skin surface covered by a red blush were similar for all the rootstocks, with the exception of fruits harvested from the trees on P 14. In this case, the fruits were significantly smaller (Table 2). There were no statistical differences between the rootstocks in respect of the colouring of the fruit.

Conclusions

1. The slowest growth in 'Elise' apple trees was induced by the rootstock M.9.
2. Growth vigour of 'Elise' trees grafted on P 60 was similar to that of the trees on M.9 EMLA.
3. Rootstock M.7 appeared to be a more dwarfing rootstock than P 14.
4. The highest cumulative yield was obtained from 'Elise' trees grafted on the standard M.26 rootstock.
5. The highest yield efficiency index was shown by 'Elise' trees growing on the Polish rootstock P 60.
6. Almost all of the trees were characterized by a similar yield efficiency index.
7. The development of fruit quality parameters (with the exception of fruit size) appeared to be unaffected by the type of rootstock.
8. In 2007, the smallest fruits were harvested from trees grafted on P 14.

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Table 1. Trunk cross-sectional area (TCA), yield and yield efficiency of 'Elise' cv. grown on dwarfing rootstocks.

Rootstock	TCA in 2007 [cm²]	Yield in				Total yield 2004-07	Yield efficiency index [kg/cm²TCA]
		2004	2005	2006	2007		
		[kg/tree]					
M.9 standard	**14.7a**	**2.5a**	**0.3a**	**10.8a**	**3.0ab**	**16.6a**	**1.2ab**
P 60	15.6ab	2.2a	1.6a	13.6ab	3.4ab	20.8ab	1.3b
M.26 standard	**20.8cd**	**2.2a**	**2.1a**	**14.1ab**	**5.8b**	**24.0b**	**1.2ab**
P 14	23.1d	2.2a	1.1a	16.2b	1.9a	21.4ab	1.0a
M.7	18.3bc	2.1a	2.4a	14.0ab	3.4ab	21.9ab	1.2ab

Averages followed by the same letter do not differ significantly at P = 0.05 (Duncan's multiple range test).

Table 2. Fruit quality of 'Elise' cv. grown on dwarfing rootstocks in 2007.

Rootstock	Mass of 100 fruits [kg]	Fruits with diameter > 7.0 cm [%]	Fruits with blush on > 75% of skin [%]
M.9 standard	**24.3c**	**96.8b**	**100.0a**
P 60	22.9bc	95.3ab	100.0a
M.26 standard	**22.3abc**	**95.9ab**	**100.0a**
P 14	19.9a	89.0a	100.0a
M.7	21.3ab	89.3a	100.0a

For explanation, see Table 1.

THE USE OF MULTIPLE REGRESSION ANALYSIS FOR STATISTICAL EVALUATION OF DATA OF A NON-ORTHOGONAL EXPERIMENT WITH SEVERAL PLUM CULTIVARS AND ROOTSTOCKS

Ivars DIMZA, Edgars RUBAUSKIS, Māra SKRĪVELE, Edīte KAUFMANE

Latvia State Institute of Fruit-Growing
Graudu 1, Dobele, LV-3701, Latvia
e-mail: edgars.rubauskis@lvai.lv

Abstract

In an orchard different plum cultivars grafted on several rootstocks in four successive years were planted. This was not an orthogonal factorial experiment therefore the results could not be evaluated by the method of variance analysis. So for this purpose the method of multiple regression analysis was used. Only two more important cultivars – 'Kometa Kubanskaya' and 'Victoria' – were chosen, grown on 8 rootstocks. As factors (independent variables) besides cultivars and rootstocks also the years in the orchard and growing seasons were chosen, but as dependent variables – the yield and the average mass of fruits. A nonlinear – quadratic – relationship between the yield and the vigour of the rootstocks was found. The highest yields were obtained from trees grafted on moderate vigorous rootstocks, in particular, Myruni. In average for all rootstocks the yield of both cultivars was almost equal. The interaction of cultivars and rootstocks was found as only a slight tendency. The yields of cultivar 'Kometa Kubanskaya' on dwarf rootstocks was relatively less than on other rootstocks. The cultivar 'Victoria' cropped less on vigorous rootstocks. The fruits of 'Victoria' in average for all rootstocks were smaller than those of 'Kometa Kubanskaya'. The effect of the rootstock on the average fruit mass was less pronounced.

Key words: correlation, interaction, fruit mass, *Prunus*, yield

Introduction

This is an attempt to apply the method of multiple linear regression analysis for statistical evaluation of a non-regular non-orthogonal plum cultivar and rootstock experiment.

The usual practice for evaluation of field experiments is to use variance analysis. This method can be used for the calculation of data of ordinary experiments with a determined number of treatments and replications, as well of orthogonal factorial experiments. However, in the praxis of horticultural research it is not always possible in one year establish a correctly designed trial. For example, a research establishment receives trees of several cultivars on several rootstocks not at once, but during several years. In such a case a suitable method must be searched for the evaluation of the obtained data. As such a method we considered the multiple linear regression analysis (MLRA). We have successfully applied this method for statistical evaluation of cumulative data of two fertilization experiments – one simple and another orthogonal factorial (Dimza and Rubauskis, 2000; Rubauskis et al., 2007).

The aim of the present research was to test the usefulness of the MLRA for the estimation of data of a non-orthogonal trial where plum trees of several cultivar-rootstock combinations were planted in a succession of years.

Material and methods

In an orchard in Dobele, Latvia, different plum cultivars grafted on 8 rootstocks of various vigour were planted during four successive years. The primary goal of this investigation was to evaluate the fitness of new rootstocks for the main plum cultivars grown in Latvia. As this was not a regular factorial experiment, the results could not be evaluated statistically by the method of variance analysis. The suitability of the method of MLRA for this goal was tested.

Only two more important cultivars – 'Kometa Kubanskaya' and 'Victoria' – were chosen. The rootstocks were arranged in a ascending succession by their vigour as follows: GF655/2; Druzhba – a hybrid between *P. armeniaca* and *P. besseyi*; SVG 11-19 – a hybrid between *P. besseyi* and *P. salicina ssp. ussuriensis* (Eremin, 2003); St. Julien A; Myruni; AP-1 (Kuban 86) – a hybrid between *P. cerasifera* and *P. persica;* PU-20651 – an open pollinated seedling of *P. cerasifera ssp. divaricata,* possibly a cross with *P. ussuriensis* (Kaufmane et al., 2007); *P. cerasifera* as factors (independent variables), besides cultivars and rootstocks and their interactions, also the years since planting and growing seasons were included in the equations. The purpose of including these variables was to eliminate their possible interference with the effects of main factors. As dependent variables the yield (kg per tree) and the average fruit mass (g) were included. For the computing of the MLRA the program SPSS for Windows was used.

More detailed description of the lay-out of the experiment is given in an earlier publication (Kaufmane et al., 2007).

Results and discussion

In model 1 only the main independent variables were included: the linear and quadratic members of rootstock vigour, and also the cultivars (Table 1). This means that the effects of these main variables can not be purified from the influence of such factors as the years since planting and growing seasons, which can significantly alter the results, since all the trees of both cultivars and various rootstocks were not planted simultaneously. For such purpose the method of MLRA is implemented. Besides, only a very small deal of variance (about 1 per cent) could be explained by the influence of the two main factors: the coefficient of determination (R^2) was merely 0.011.

The role of rootstocks may be reflected both by the linear and the quadratic member of the equation. However, the coefficient of the former is so negligible that it must be abandoned. On contrary, the significance of the other variable – the rootstock square – was sufficiently high – the p-value was 0.043. As the value of the regression coefficient was negative (-0.121) there was a distinct optimum. Usually this has a meaning for quantitative variables, for example, doses of fertilizers. However, in this case we have a qualitative variable and one could wonder how such a variable can have optimum. Happily, the rootstocks were arranged after their vigour. Consequently, this optimum means that on the average for both cultivars the highest yields were obtained from trees

on middle vigorous rootstocks. This is visualized in Figure 1, where the yield curves, calculated by the equation (model) 1 are confronted with the real values for all the 8 rootstocks (Table 1).

The theoretically calculated yields of plums increase along with the vigour of rootstocks, till it reaches the optimum – the highest level – for the middle vigorous rootstock Myruni (average 19.1 kg per tree), which is less vigorous than AP-1, PU-20651 and *P. cerasifera* (Figure 1). The plum grafted on the latter as the most vigorous rootstock, cropped less – even slightly less than on the dwarf rootstock GF 655/2, and approximately as much as on other dwarf rootstock Druzhba (Figure 1). The real yield of cultivar `Kometa Kubanskaya` on the rootstock Myruni also was the highest amongst all the tested rootstocks (23.2 kg per tree). Moreover, this real value considerably exceeds the theoretical calculated one. Unfortunately, the design of the trial was not orthogonal, that is, both cultivars were not grafted on all 8 rootstocks. Consequently, the real value of yield for the cultivar 'Victoria` on the rootstock Myruni is not obtained (Figures 1, 2). The most discordance between the theoretical and real values was observed with the dwarf rootstock GF 655/2. The latter considerably exceeded the former. This may be connected with peculiar properties of this rootstock which enhance the cropping of scion cultivar.

In equation (model) 2 also the interactions of factors and other independent variables – the years since planting and the number of growing season – are included (Table 1, Figure 2). In this case their interfering influence on the effects of main factors must be removed. Indeed, the statistical parameters are essentially improved. The coefficient of determination increases from 0.011 to 0.134; that is 13.4 % of variations of the yield can be explained by the influence of factors. True, the regression coefficient for the linear member of the rootstocks also in this case is near zero. That means that in average the yield does not increase with the vigour of rootstocks. But on the other hand, the optimum of the vigour of the rootstocks is more pronounced: the negative regression coefficient for the quadratic member increases from –0.121 to -0.193. This

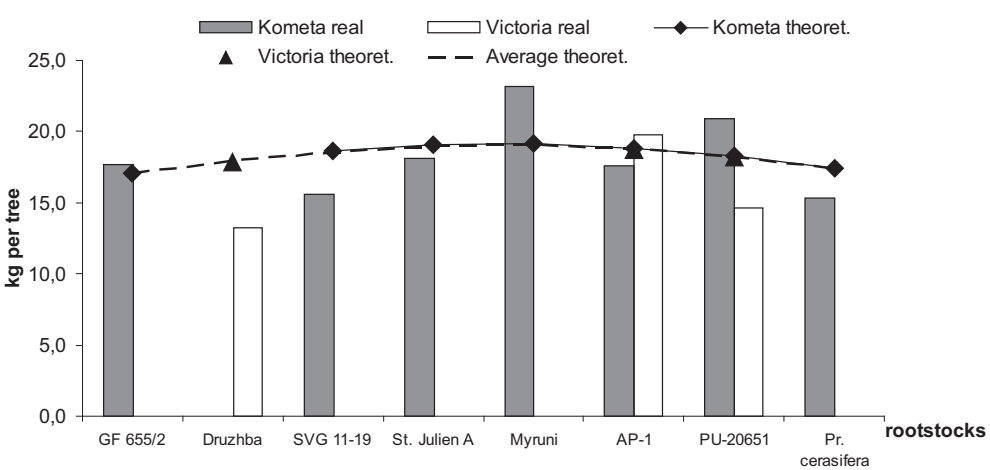

Figure 1. The yield of plum cultivars 'Kometa Kubanskaya` and 'Victoria' depending of rootstocks (Equation 1 in Table 1)

can be seen comparing the two curves reflecting the dependence of the rootstocks vigour on the yield (Figures 1, 2). When the curves corresponding to the equation 1 exhibit only a slight bend about the rootstocks St. Julien A, Myruni and AP-1, then these corresponding to equation 2 show a distinct optimum by the rootstocks St. Julien A and Myruni. On the contrary, the curve of the first equation does fit the real values of yield on all the rootstocks a little better (Figure 1). This must not be surprising, as they derive only from these real values. However, as mentioned above, not all the trees of various cultivar – rootstock combinations were planted at once, therefore their yield can be influenced by the age of trees and also weather conditions in a different way. Consequently, the curves in Figure 1 likewise as the empirically obtained values do not reflect exactly the real functional relationship. On the contrary, the curves in Figure 2 reflect the values that are purified from the said interfering influences. Therefore, they reflect the character of dependence of the yield from the vigour of rootstocks more truly. Consequently, the method of MLRA has been proved effective for removing of meddling side-effects from the influence of main factors.

The biological meaning of the optimum for the rootstock vigour may be explained in two ways. The relatively low yields of plums on the dwarf rootstocks are due to smaller volume of tree canopy, as the yields were calculated as kg per tree. However, since the smaller trees may be planted closer than the vigorous ones the yields in tons per ha must be higher. One could be surprised about the relatively low yields on the most vigorous rootstocks. Yet this may be explained by the relatively young age of the trees: evidently the more vigorous ones had not reached the period of full bearing. Indeed the cropping of all the trees in average (including the dwarf ones) improved throughout the duration of the experiment, as indicated by the highest degree of significance of the linear member of the independent variable "growing season" (p-value is 0.02 in the equation 2 (Table 1). However, during the period of the trial the yields exhibited a slight tendency to slow down the rate of growth towards the end of this period, as shown by the negative regression coefficient (-0.03) for the quadratic member of this variable.

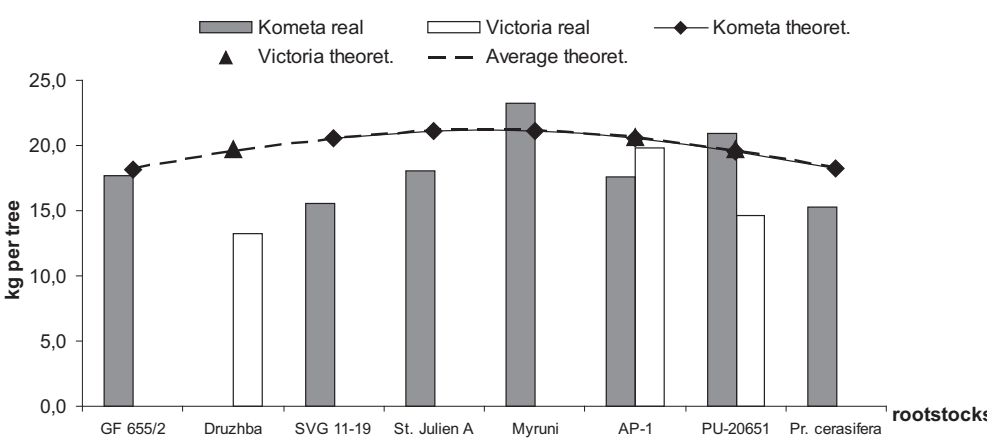

Figure 2. The yield of plum cultivars 'Kometa Kubanskaya` and 'Victoria' depending of rootstocks, theoretical values are purified from the said interfering influences (Equation 2 in Table 1)

However, for growers no less important is the question how various rootstocks influence the cropping of different cultivars. This may be indicated by the interaction of the variables. Unfortunately, the interactions of the factors exhibit only slight tendencies. Nevertheless they have a logical meaning. The negative regression coefficient (-0.07) of the interaction of rootstocks and cultivars means that the yields of the less vigorous cultivar 'Kometa Kubanskaya' (coded with -1) on dwarf rootstocks are less than on the vigorous ones; that can be explained by the smaller volume of such trees, thus less cropping potential. On the other hand, the relatively vigorous cultivar `Victoria` on vigorous rootstocks also had smaller yields, but in this case the cause may be delayed cropping. However, the absolute values of the regression coefficient for this interaction are too small to have any practical meaning.

Surprising is the absence of significant differences between yields of both cultivars in average for all the rootstocks, as biologically they differ very much. They belong to different plum groups – 'Kometa Kubanskaya' is *P. salicina* × *P. cerasifera,* while 'Victoria' is *P. domestica*. However, they have common points – they both bear fruits on last year's growth.

The average mass of plum fruits was not significantly influenced by the vigour of rootstocks. Neither the linear, nor the quadratic members of this factor were big enough to be significant. Their p-level was respectively 0.986 and 0.207 (Table 2). On the contrary, the significance of the factor cultivar was very high – the p-value was 0.004. The fruits of the cultivar 'Kometa Kubanskaya' were significantly larger than the ones of cultivar 'Victoria'. The interaction of cultivars and rootstocks was not significant (p-value -0.43); that means that the difference in the fruit mass between the cultivars was not dependent on the vigour of rootstocks. Unexpected was the influence of the factor "years since planting". The regression coefficients for both the linear and quadratic members are negative, besides the significance of the latter is very high. Evidently, the biggest fruits were obtained in the middle of the period of the investigation with a slight decline towards its end.

Conclusions

The method of multiple linear regression analysis has been proved useful for statistical evaluation of a non-regular non-orthogonal experiment with two plum cultivars and several different rootstocks. With means of composing and solving quadratic equations relationships between the yield, and also fruit size and vigour of rootstocks were found out. Including in the equations auxiliary independent variables – the growing season and the years since planting, it was possible to purify the main effects from the interfering influence of these variables and this improve the results.

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Table 1. Regression coefficients (β) reflecting the influence of the several factors on the yield of plums (kg from tree) and level of significance (p-value)

Independent variables	equation 1 R^2 0.011		equation 2 R^2 0.134	
	β	p-value	β	p-value
Constant	19.165	—	18.889	—
Rootstock (R)	0.047	0.431	0.005	0.958
R^2	-0.121	0.043	-0.193	0.011
Cultivar (CV)	-0.041	0.488	0.079	0.285
Years since planting (T)			-0.227	0.317
T^2			0.071	0.472
Growing season (GR)			0.507	0.020
GR^2			-0.030	0.756
R × CV			0.057	0.618
R × T			0.250	0.246
R × GR			-0.115	0.560
CV × T			0.423	0.040
CV × GR			-0.489	0.012
R × CV × T			0.038	0.611

Table 2. Regression coefficients (β) reflecting the influence of several factors on the mass of plums (g) and level of significance (p-value): equation 3; R^2 0.229.

Independent variable	β	p-value
Constant	31.597	-
Rootstock (R)	0.002	0.986
R^2	0.090	0.207
Cultivar (CV)	-0.202	0.004
Years since planting (T)	-0.324	0.131
T^2	-0.264	0.005
Growing season (GR)	-0.113	0.581
GR^2	0.027	0.762
R × CV	-0.085	0.430
R × T	0.204	0.315
R × GR	-0.322	0.084
CV × T	-0.092	0.634
CV × GR	0.092	0.616
R × CV × T	-0.002	0.981

EVALUATION OF PEAR CULTIVAR 'SUVENĪRS' ON DIFFERENT ROOTSTOCKS

Inese DRUDZE, Jānis LEPSIS

Pure Horticultural Research Centre, Abavas 2, Pūre, LV-3124,
e-mail: inese.drudze@puresdis, janis.lepsis@puresdis.lv

Abstract

Since 1999 a trial was established with the aim to select most appropriate rootstocks for intensive orchards of pear cultivar 'Suvenīrs'. Dwarfing quince rootstocks BA 29, QA un QC (with and without compatible interstock 'Štaras31'), semidwarf *Pyrus communis* group rootstocks 'Pyrodwarf' and 'Old Home' x 'Farmingdale' (OH x F333), and vigorous *Pyrus communis* group rootstocks 'Kirchensaller Mostbirne' and local population 'Kazraušu bumbiere' were chosen for trial.

The first differences were observed in nursery. QC was inappropriate due to low winter hardiness. Quince BA 29 was the best for Latvian climate conditions. The highest quality planting material was obtained for trees grafted on 'Pyrodwarf'. Rootstocks OH x F333 and 'Kirchensaller Mostbirne' induced the development of lateral branching of one year old trees. In Latvian climate these branches were not winter hardy enough, and therefore were not useful for young tree crown formation.

In 2001, the trees were planted in orchard for further evaluation. The first indications of incompatibility between cultivar and rootstock were observed in the 4th year after planting for all quince group rootstocks. In the variants with interstock incompatibility was stated in the 6th year.

The difference in tree height became significant during the 6th – 7th years. In all variants, using quince with interstock 'Štaras31', tree height and productive volume of crown was significantly higher, but not exceeding 3 m in height. Trees on 'Pyrodwarf' grew more vigorously than on OH x F333, and their growth habit had a tendency to approach trees on vigorous rootstocks. Since 8th year, rootstocks 'Pyrodwarf' and 'Kirchensaller Mostbirne' started to develop root sprouts in all area of crown projection. Significant fluctuations in yield and fruit size were not stated until now. Most appropriate solutions for increasing the development of fruit twigs for 'Suvenīrs' are not found yet.

Key words: compatibility, *Pyrus communis*, root sprouts, tree height

Introduction

There is poor choice of pear rootstocks in Latvian conditions. All rootstocks used till now are only seedlings of local origin. Trees on these rootstocks are winter hardy and mostly high yielding, but often too vigorous for commercial plantations, especially when grafted cultivar has naturally vigorous growth habit. Therefore it is very actual to find rootstocks with dwarfing tendency.

Second serious problem in commercial pear growing in Latvia is lack of compatible interstocks for dwarfing quince (*Cydonia oblonga*) group rootstocks. Cultivars compatible to quinces widely used in commercial gardens of West European countries are inappropriate for growing in Latvian climate because of insufficient winter hardiness. No one Latvian commercial pear cultivar is fully compatible with quinces. The possible source of appropriate compatibility donors are local genetic resources.

Another way can be the using of natural dwarfing or semidwarfing habit selections of *Pyrus communis* usually having no problems with compatibility. For that reason in trial were included rootstocks 'Pyrodwarf' and OH x F333. In Germany they have better winter hardiness and compatibility in comparison to the quince group rootstocks (Jacob, 1996; Weber, 2001).

Previously it was observed for some pear cultivars that dwarf habit pear trees have more serious frost injuries on buds than vigorous trees because productive buds are located in the height threatened by winter and late spring thaws, typical for Latvian climate, interchanging with frost periods. Probably it causes irregular yielding of typical dwarf pear trees. It is not investigated in Latvia yet.

The general aim of the trial was to test cultivar compatibility of 'Suvenīrs' with rootstocks, possible modifying effects on crown habit, winter hardiness, yield capacity and fruit quality. Cultivar 'Suvenīrs' has genetically very vigorous growth habit with small amount of fruit twigs, therefore it is necessary to find methods for optimal tree pruning and training, including branch bending.

Materials and methods

The trial is a part of a complex international scientific project on rootstocks evaluation, where Latvia, Estonia, Lithuania and Byelorussia are included.

Dwarfing quince rootstocks BA 29, QA un QC (in two grafting variants – without compatible interstock and with double inoculation (nicolation) of 'Štaras 31'), semidwarf *Pyrus communis* group rootstocks 'Pyrodwarf' and OH x F333, and vigorous *Pyrus communis* group rootstocks 'Kirchensaller Mostbirne' and local population 'Kazraušu bumbiere' were chosen for trial. 'Štaras 31' is a selection made in Lithuania and is widely used in commercial pear plantations in Byelorussia to prevent physiological incompatibility with the quince rootstock.

All quince group rootstocks, 'Pyrodwarf' and OH x F333 were vegetative propagated and virus free. Open pollination seedlings 'Kirchensaller Mostbirne' and 'Kazraušu bumbiere' were not virus tested.

The first observations were made in nursery. The winter hardiness, the percentage of standard planting material and tendency to develop lateral branching were registered for each rootstock combination during 1999-2000.

In 2001, the plant material was planted in orchard for further evaluation. Planting distances for trees on quince group rootstocks was 2 x 4 m, on 'Pyrodwarf' and OH x F333 – 3 x 4 m, on 'Kazraušu bumbiere' and 'Kirchensaller Mostbirne' – 5 x 5 m.

The trial was designed as randomised blocks in three replications for each rootstock combination. In each plot were planted three trees. Cultivars 'Conference', 'Talsu Skaistule' and 'Beloruskaya Pozdnaya' were grafted on tops of isolation trees as pollinators.

Indications of physiological incompatibility on different rootstocks were scored visually, where 1 point- no signs of incompatibility, 3 points – red coloration of leaves in summer, 5 points – perished trees. The number of perished trees in each plot was registered also.

Results and discussion

Quality of planting material. Observations in nursery showed that the QC rootstock was not suitable for Latvian climate conditions due to unsatisfactory winter hardiness. After fist winter the level of unsuccessful grafts on QC was 66.3%, on QA – 13.8%, on BA 29 – 11.8%. Heavy frost damages on bark of rootstock caused such high level of death of grafted buds on QA. Quince BA 29 was selected in nursery as probably the best winter hardy quince group rootstock for Latvian climate conditions (Lepsis, Drudze, Dekens, 2004).

All of the *Pyrus communis* group rootstocks showed satisfactory winter hardiness in nursery. Some differences were observed only in vegetative parameters of young trees. Rootstocks OH x F333 and 'Kirchensaller Mostbirne' induced the development of early lateral branching of one year old trees. In Latvian climate these branches were not winter hardy enough, and therefore were not useful for young tree crown formation. Plants on all *Pyrus communis* group rootstocks were approximately 30 cm higher than on quinces. The highest amount of standard quality planting material was obtained on 'Pyrodwarf'.

Compatibility between rootstocks and cultivar 'Suvenīrs'. Complete physiological compatibility with 'Suvenīrs' was not found for no any of investigated quince rootstocks. The first indications of physiological incompatibility between cultivar and rootstock – red leaves in early summer – were observed in the 4th year after planting for all quince group rootstocks. In 2007, the percentage of trees of unsatisfactory compatibility with QA and QC was close to 50 % from initially planted trees. 'Štaras 31' as a compatible inter-stock also did not show acceptable level of compatibility. In the plots with 'Štaras 31' as inter-stock the first indications of incompatibility were stated approximately two years later. There was observed significant differences in influence of inter-stock 'Štaras 31' on trees dependently on rootstock (Table 1).

The best compatibility was observed in rootstock/inter-stock combination QA + 'Štaras 31', where only one tree had perished because of incompatibility until 2007. If such tendency will remain in following seasons, probably 'Štaras 31' will be appropriate for commercial use with QA in Latvian climate conditions. Combination QA + 'Štaras 31' in Pure also showed one of the highest yield per tree and per hectare till 2006. Similar observations were made also in Lithuania. In contrary, in combination with most winter hardy and healthy quince group rootstock BA 29, inter-stock of 'Štaras 31' showed insufficient compatibility level. In average 33% of trees in plots perished until 2007. For that reason it is recognized that 'Štaras 31' may not be usable for BA 29. More compatible inter-stock for BA 29 must be searched in future.

All of *Pyrus communis* group rootstocks showed good visual compatibility – healthy green leaves during growing season.

In 2007, development of root sprouts in all area of crown projection was observed for trees on rootstocks 'Pyrodwarf' and 'Kirchensaller Mostbirne' (Table 2).

The reason of root sprout development was not investigated. Possibly root sprout development indicates first slight incompatibility, or maybe it is a genetic feature of rootstock. There were no other provocative factors in orchard – such as soil cultivation in crown projection zones that can induce mechanical root damages with following

sprouting. 'Pyrodwarf' is a vegetative propagated rootstock, in contrary – 'Kirchensaller Mostbirne' is a seedling rootstock, so there is no reason to relate this fact with the rootstock propagation method. Hopefully the exact reason of root sprouting will be cleared up in following investigation seasons. In any way the root sprouting was rated as an undesirable property of rootstock, making it difficult to use some systemic herbicides in orchard.

Tree crowns. Until 2005 no significant differences in tree height on different rootstocks was observed. The difference in tree height became significant in the 6th – 7th year from planting. In 2006 – 2007 trees on *Pyrus communis* group rootstocks started grow more actively than on quinces. In all variants, using quince with inter-stock 'Štaras31', tree height was significantly higher than on quinces without inter-stock, but still not exceeding 3 m in height. A similar tendency was observed also in the productive volume of crown and in crown projection. Trees on 'Pyrodwarf' grow more vigorously than on OH x F333, and have a tendency to approach vigorous growth habit rootstocks (Table 3). Both seedling group rootstocks 'Kirchensaller Mostbirne' and 'Kazraušu bumbiere' induced very vigorous growth for 'Suvenīrs'.

Yield. Significant difference in yield and fruit size until 2006 was not stated. Only in 2006 the first commercially valuable yield was harvested (Figure 1).

Usually trees on vigorous seedling origin rootstocks start yielding in the 5th year after planting. Trees on dwarfing and semi-dwarfing rootstocks must have to start yielding more early, but it does not happen because of regular spring frosts. In 2007 there were extremely heavy frost damages of flower buds, therefore all of the fruits were defective and yield was not recorded.

The average yield per tree in 2006 was significantly higher on 'Kazraušu bumbiere', but the highest yield per hectare was observed on quince group rootstocks with compatible inter-stock. Semi-dwarf rootstocks 'Pyrodwarf' and OH x F333 showed lowest yield per tree and were close to vigorous seedling group rootstocks in yield per hectare.

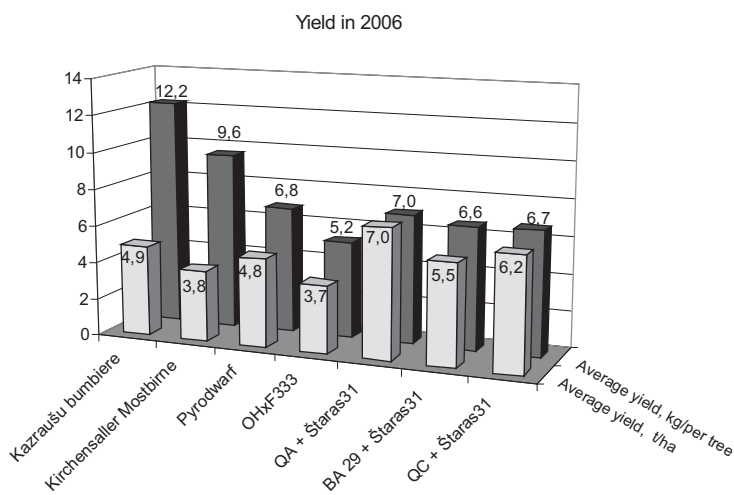

Figure 1. The average yield per tree and per hectare in 2006

Only one season of yield recording does not give exact data of possible yielding potential on different rootstocks. It is clear that influence of spring frost and thaws can seriously restrict the yield of dwarf and semi-dwarf habit pear trees in Latvian climate conditions. Even the yielding of vigorous habit trees can be irregular. In 2008 normal yield is expected and observations of yield and fruit quality can be started.

Pruning systems. Cultivar 'Suvenīrs' has genetically very vigourous growth habit with small amount of fruit twigs, therefore to find methods for optimal tree pruning was necessary. The most appropriate solutions for increasing the development of fruit twigs are not found yet.

In 2007 the most promising results were in variants with double cutting of one year old twigs in early spring and in summer and by bending of branches under 60-90^{O} angle with leaving tops upright. These variants were selected for further evaluation in 2008.

Conclusions

Double grafting (nicolation) in nursery can be used as a method for preventing the physiological incompatibility for quince group rootstocks.

'Štaras 31' as a compatible inter-stock is usable for QA, but for BA 29 it can not give satisfactory compatibility level.

Rootstocks 'Pyrodwarf' and 'Kirchensaller Mostbirne' have problems connected with rich developing of root sprouts in all area of crown projection.

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Table 1. Influence of compatibility inter-stock 'Štaras 31' on quince group rootstocks

Rootstock	First indications of incompatibility, % from initially planted trees		Perished trees, % from initially planted trees		Total percentage of trees with incompatibility indications, % from initially planted trees
	2001-2006	2001-2007	2001-2006	2001-2007	2001-2007
BA 29	8 b	8 b	0 a	8 b	16 b
BA 29 + Štaras 31	0 a	0 a	17 b	33 c	33 c
QA	8 b	33 c	0 a	17 b	50 d
QA + Štaras 31	0 a	0 a	0 a	8 b	8 a
QC	33 c	17 b	17 b	33 c	50 d
QC + Štaras 31	0 a	8 b	8 b	33 c	41 c
p	*0.000*	*0.000*	*0.000*	*0.000*	*0.001*

Table 2. Development of root sprouts and incompatibility

Rootstock	Root sprouts, 0-5 points	Incompatibility between cultivar/rootstock, 1-5 points
BA 29+ Štaras 31	0.63 a	2.33 b
QA+ Štaras 31	0.00 a	1.00 a
QC+ Štaras31	0.67 a	1.22 a
OH x F333	0.00 a	1.00 a
Pyrodwarf	4.17 b	1.00 a
Kirchensaller Mostbirne	1.67 a	1.00 a
Kazraušu bumbiere	1.17 a	1.00 a
p	*0.000*	*0.000*

Table 3. Vegetative parameters of tree growth habit in 2007

Rootstock	Tree height, m	Trunk cross section area, cm^2	Crown volume, m^3	Crown projection, m^2
BA 29+ Štaras 31	2.90 a	33.1 a	3.38 ab	3.47 ab
QA+ Štaras 31	2.82 a	31.2 a	2.98 a	3.18 a
QC+ Štaras31	2.61 a	27.0 a	2.00 a	2.29 a
OH x F333	3.27 b	48.7 b	4.85 bc	4.44 bc
Pyrodwarf	3.38 bc	54.1 bc	5.28 c	4.69 c
Kirchensaller Mostbirne	3.72 c	67.8 cd	7.46 d	5.97 d
Kazraušu bumbiere	3.63 bc	72.7 d	8.40 d	6.91 d
p	*0.000*	*0.000*	*0.000*	*0.000*

THE ESTIMATION OF SOME SWEET CHERRY (*PRUNUS AVIUM* L.) HYBRIDS AT THE LATVIA STATE INSTITUTE OF FRUIT GROWING

Daina FELDMANE, Silvija RUISA

Latvia State Institute of Fruit–Growing
Graudu 1, Dobele, LV-3701, Latvia
e-mail: silvija.ruisa@lvai.lv, daina.feldmane@inbox.lv

Abstract

To obtain cultivars of high fruit quality and better winterhardiness than available ones at present, the breeding program was started in Latvia State Institute of Fruit- Growing since 1996. Acording to this program the local cultivar 'Aija'; hybrid AM 24-10-22 and introduced cultivar 'Brjanskaja Rozovaja', which are winterhardy, were crossed with large-fruited cultivars of West and South European as well as Canadian origin. As a result 412 hybrids were planted out on field in year 2000, of which 20 hybrids were selected and evaluated during 2006 – 2007 for tree height and habit, winter hardiness of trees, winter hardiness of flower buds, productivity and fruit quality.

All selected hybrids are winterhardy. High winterhardiness of flower buds have hybrids 24-2-33; 24-3-6; 24-4-4. Good yields were obtained from the hybrids 24-2-33; 24-3-6; 24-4-4. The best fruit quality have hybrids 24-2-33; 24-4-22; 24-4-25.

The estimation of the best hybrids will be continued after their grafting on rootstock *Gisela 5* .

Key words: fruit quality, efficiency of production, winter-hardiness

Introduction

Winter frost is the uppermost limitative factor for sweet cherry growing in Latvia, where the air temperature in winter often is rather low and very unsteady. It is necessary to obtain sweet cherry cultivars with better winter-hardiness, especially for their flower buds. Sufficient flower density is a precondition of high productivity. Although sweet cherries are growing in Latvia for a long time, however, there is a lack of winter-hardy cultivars with high-quality fruits. Previous researches has proven that cultivars 'Aija', 'Brjanskaja Rozovaja' are winter-hardy and productive; the local hybrid AM 24-10-22 also is winter-hardy and of high tolerance to diseases, but its productivity is low (Dekens, 1996; Ruisa 1998). To provide sweet cherry growing profitability, the fruit quality has to be improved. Fruit quality of cultivars 'Lapins', 'Rainier', 'Van', 'Krupnoplodnaja' is high, but their winter-hardiness is unsatisfactory in Latvian conditions. (Olmstead et al., 2000; Ruisa, 1998)

According to the Latvia State Institute of Fruit-Growing breeding program, winter-hardy sweet cherry cultivars 'Aija', 'Brjanskaja Rozovaja', and hybrid AM 24-10-22 were crossed with large fruited cultivars 'Lapins', 'Van', 'Rainier' to obtain cultivars of high fruit quality and good winter-hardiness. The aim of this research is to estimate the acquired hybrids for their height and tree habit, winter-hardiness of trees and flower buds, flowering, productivity and fruit quality.

Material and methods

Research was performed at Dobele, in the Latvia State Institute of Fruit-Growing selection orchard. As a result of purposed crossing 412 hybrids were planted out in field in year 2000, at planting distances 3 x 4 m. They were cultivated on brown lessive loam soil (OM – 2,3 %, $pH_{K\ Cl}$ – 7,3, P_2O_5 – 67 mg kg^{-1}, K_2O – 129 mg kg^{-1}). Eleven best hybrids were selected and evaluated during 2006 – 2007: 24-2-33, 24-2-35, 24-3- 6, 24-3-9, 24-3-51, 24-3-33, 24-4-22, 24-4-25, 24-4-28, 24-4-44, 24-4-33, 24-4-63. The introduced cultivar 'Iputj', which is winter-hardy, productive and has fruits with good quality, was used as a control.

In February 2007 air temperature rashly decreased after enduring warm December and January. It partially affected flower buds of all hybrids and the control cultivar. Significantly more precipitation and lower air temperature were observed during flowering time (first half of May) in 2007 than in 2006. After this unfavourable weather additional productive hybrids were selected and evaluated: 24-2-32, 24-3-27, 24-3-33a, 24-5-1, 24-5-3, 24-5-4, 24-5-6, 24-4-4, 24-4-11.

For the evaluation of sweet cherry hybrids the following criteria were used:

- height of trees (m) and tree habit,
- winter hardiness of trees and of flower buds (0 – 5 points),
- productivity (yield efficiency – yield mass, kg per 1 cm^2 trunk cross section area),
- fruit quality (fruit mass in g, appearance and taste in points (1 – 5), content of soluble solids in ^{o} Brix).

These criteria were determined without replications, because each tree is seedling. Yield efficiency and fruit quality were evaluated only in 2007, because birds wasted the yield in summer of 2006. Parallel analysis was used for fruit quality parameters determination. The content of soluble solids (^{o}Brix) was determined with a digital refractometer ATAGO N20 (deviation of measuring instrument face value ±0.1%) (ISO 2173:2003) at the Laboratory of Biochemistry.

Additional were used criteria for:

- flowering (flower density per 1 cm shoot length, flowering index – proportion between blossom number and sum of blossom and leaf number),
- productivity (fruit set on %, crop density – number of fruit per 1 cm shoot length).

These criteria were determined in three replications – one branch was observed as one replication. Analysis of variance (MC Excel, ANOVA: Single factor) and F criterion was used for probability test, also coefficients of correlation were determined.

Results

Hybrids 24-4-4 and 24-4-28 had the most compact habit – their length (4 m) and crown size were significantly less in comparison to control cultivar (4.3 m). Other hybrids length was from 4.1 to 5.1 m.

Trees – trunk, branches, shoots of all selected hybrids were sufficiently winter-hardy to endure air temperatures –25 … –27 ^{o}C degrees after thaw. Hybrids 24-2-33, 24-3-6 and control cultivar 'Iputj' had the best winter-hardiness of flower buds (Table 1).

The average flower density per 1 cm shoot length of all hybrids and control cultivar was 0.6 in 2006, but only 0.1 in 2007 due to indistinctive, unfavourable winter. Hybrids 24-2-33 and 24-3-6 had the best flowering indices in both years; there were no significant differences with the control cultivar ($p < 0.05$) (Figure 1)

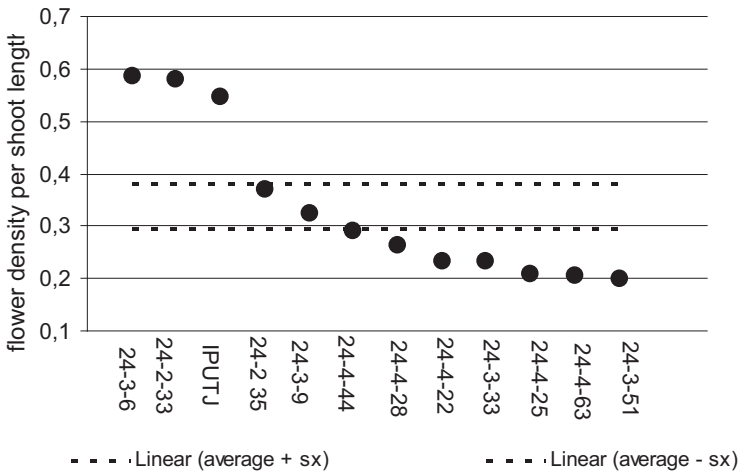

Figure 1. Flower density of sweet cherry hybrids per 1 cm shoot length (the average of years 2006 – 2007)

There were significant differences in fruit set of sweet cherries in dependence of year. The average fruit set of all hybrids and control cultivar was higher in 2006 (51 %), than in 2007 (30 %) due to diverse weather conditions in flowering time ($p < 0.05$). Differences between hybrids and control cultivar in fruit set were not significant in both years ($p < 0.05$).

Due to unfavourable winter and spring, the average productivity was significantly lower 2007 than in 2006 too ($p < 0.05$). The average crop density of all hybrids and control cultivar was 0.32 fruits per shoot length cm in 2006, but only 0.02 fruits per shoot length cm in 2007.

Hybrids 24-4-4, 24-2-33 and 24-3-6 were the most productive in both years. Hybrids 24-4-4 and 24-2-33 had the highest yield efficiency, it was significantly higher than that of control cultivar 'Iputj' yield efficiency; their crop density (0.3 – 0.4 fruits per shoot length cm on average in 2006 – 2007) did not differ significantly with control cultivar. Hybrids 24-3-6 yield efficiency and crop density did not differ from the control cultivars yield efficiency ($p < 0.05$) (Figure2).

Flower density positively correlated with crop density ($r = 0.9$) and yield efficiency ($r = 0.7$).

The hybrids 24-4-25, 24-4-22, 24-4-28 and 24-2-33 had the best fruit weight; it was significantly bigger than control cultivar 'Iputj' fruit weight. The difference of fruit weight of hybrid 24-3-6 if compared to the control was insignificant (Figure 3) ($p<0.05$).

Fruit mass of one of the most productive hybrids 24-4-4 was only 5.2 g. It was significantly lower than control cultivar fruit mass ($p<0.05$).

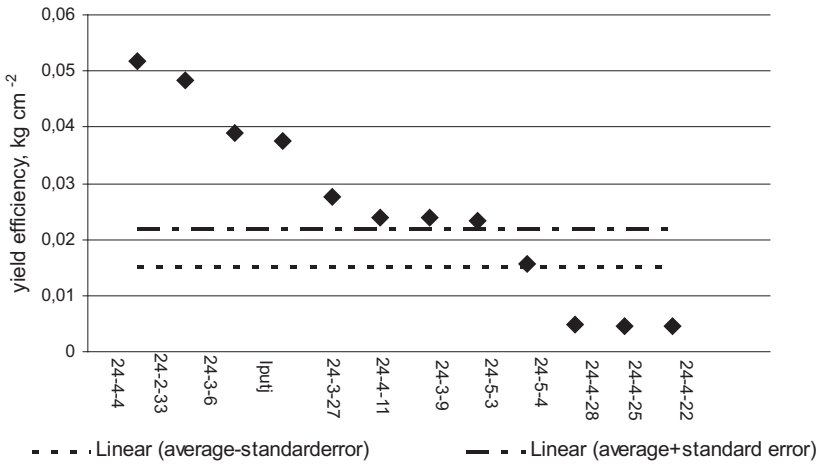

Figure 2. Yield efficiency of the selected sweet cherry hybrids (the average of years 2006 – 2007)

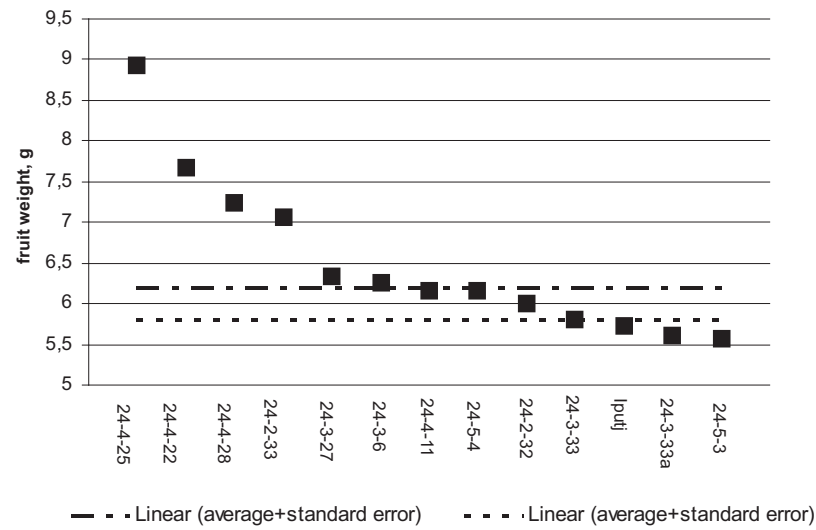

Figure 3. Fruit mass (g) of the selected sweet cherry hybrids

Fruits appearance evaluation for hybrid 24-4-25 (4.9 points) was significantly higher than for control cultivar. Sweet cherry hybrids 24-3-27, 24-4-22, 24-5-4, 24-4-28, 24-2-33, 24-4-11, 24-5-1 and control cultivar 'Iputj' fruit appearance was evaluated in 4.5 – 4.8 points, there were not significant differences between them. Hybrid 24-4-4 had significantly lower fruit appearance evaluation – 3.5 points ($p < 0.05$).

All hybrids had significantly higher content of soluble solids in fruits (15.6 – 22.7 ^{o}Brix) than control cultivar 'Iputj' (14.0 ^{o}Brix).

Hybrids 24-3-9, 24-4-22 and 24-5-4 had the highest fruit taste evaluation – 4.7 points. Average fruit taste evaluation was 4.4 points, control cultivar taste evaluation was 4.5 points. Differences between hybrids and control cultivar fruit taste evaluation were not significant ($p < 0.5$).

Discussion

Large fruit weight mostly is one of the breeding objectives. In Latvian conditions as sufficiently large fruit weight of cherries is considered 5.5 – 7 g (Dekens, 1996). It is less than fruit weight of the best cultivars of South and West European origin, most likely due to the climatic differences – less yearly accumulative temperatures and shorter frost free period. Russian and Estonian sweet cherry cultivars which are growing in similar or more unfavourable climatic conditions also have fruit weight approximately 4.0 – 5.5 g (Kanshina, 1999; Kask, Jänes, 1996).

For example, in China four sweet cherry cultivars from several regions with different elevations were observed. Fruits of three cultivars had the smallest fruit size and the highest content of soluble solids at the highest elevation, where the lowest yearly accumulative temperatures and shorter frost free period were observed (Lu Xiu Lan et al., 2005).

Inheritance of fruit characters in progenies from crosses of sweet cherry cultivars has been studied; fruit size was evenly distributed in progeny with respect to the fruit size of their parent plants (Theiler- Hedtrich, 1994). Fruit weight of most sweet cherry hybrids in our research was within the range of the parent plants. Only hybrid 24-4-25 fruit weight (8,9 g) was greater than fruit weight of both parent cultivars – 'Rainier' (7 g) and 'Aija' (4 – 4.5 g) (Ruisa, 2005). So inheritance of fruit weight and size is not always obvious.

In several studies was concluded that sweet cherry productivity correlates negatively with fruit weight and content of soluble solids. For each sweet cherry cultivar a different model of this relation was obtained (Tersoglio et al., 2004; Lang, Ophardt, 2000). However this connection emerges not in all cases (Franken-Bembenek, 1998; Sansavini, Lugli, 1998). In our research productivity and fruit weight did not correlate due to genetic differences of sweet cherry hybrids: they are from several cross combinations. It is not known how fruit weight will change after grafting on different rootstocks.

Conclusions

The most compact tree habit had the hybrids 24-4-4 and 24-4-28.

All selected sweet cherry hybrids had good winter-hardiness of trees.

Sweet cherry hybrids 24-4-4, 24-2-33 and 24-3-6 had the best indices of winter-hardiness of flower buds, flowering and productivity.

Sweet cherry hybrid 24-4-25 had the best indices of fruit quality: the biggest fruit mass – 8.9 g, and the highest evaluation of fruit appearance – 4.9 points.

Sweet cherry hybrids 24-4-22, 24-4-28, 24-2-33 had good fruit quality too. Their fruit mass was significantly bigger than control, and their evaluation of fruit appearance did not differ from control.

Fruits of all hybrids had significantly higher content of soluble solids than control cultivar 'Iputj'.

Differences of fruit taste among the hybrids and control were not significant.

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Table 1. Sweet cherry hybrids winter-hardiness of flower buds

Hybrids of sweet cherries and control cultivar	Winter-hardiness of flower buds, points	
	Lower zone of crown	Middle and upper zone of crown
'Iputj'	3	5
24-2-33	3	5
24-3-6	3	5
24-3-9	2	4
24-3-33	1	4
24-2-35	1	3
24-4-22	1	3
24-4-28	1	3
24-4-25	0	3
24-3-51	1	1
24-4-44	0	1
24-4-63	0	0
Average	*1.3*	*3.1*
Standard error	*0.3*	*0.5*

STUDY OF NEWLY INTRODUCED CULTIVARS OF BLACK AND RED CURRANT

Diyan GEORGIEV, Hristina DINKOVA, Mariya GEORGIEVA

Institute of Mountain Stockbreeding and Agriculture
Troyan 5600, 281 Vasil Levski Street
e-mails: d_georgiev_@abv.bg, kris05@abv.bh, Maria_Georgieva_bg2000@yahoo.fr

Abstract

During the last years the interest in the fruits of black and red currant became stronger due to their rich biochemical composition, exerting a favourable influence on human health. That necessitates studying and introducing new varieties into practice that are characterized by good adaptability to the specific soil and climatic conditions and high fertility.

During the 2002-2007 period, at the Institute of Mountain Stockbreeding and Agriculture in Troyan a study was conducted on the phenological stages, vegetative and reproductive characteristics of three cultivars of black currant ('Ometa', 'Hedda' and 'Silvergieters Schwarze') and two cultiavrs of red currant ('Rovada' and 'Jonkheer van Tets').

The earliest beginning of vegetation was observed for cultiavar 'Hedda' and among the red currant cultivars for 'Jonkheer van Tets' (end of March and first half of April). The black currant cultivars 'Ometa' and 'Silvergieters Schwarze' and the red currant cultivar 'Rovada' were distinguished for the largest number of fruits per bunch. The highest average yield per bush was obtained from the cultivars 'Ometa' – 1.59 kg and 'Rovada' – 1.21 kg.

Key words: black currant, red currant, cultivars, fruits, yield

Introduction

Black and red currants have long been known in Bulgaria. Scientific work with them began in the second half of the past century. Its results show that agrometeorological conditions in the region of the Central Balkan Mountains provide optimum conditions for growth and fruit-bearing of these crops (Dimov, 1970; Dokova, 1970; Vlaskovski, 1976).

The agrarian reform taking place in the last years in Bulgaria, on the one hand and the rich biochemical composition of their fruits and their suitability for processing into various products, on the other hand, are a prerequisite for the increased interest in this fruit crop lately (Lenartowicz et al., 1990; Plocharski et al.; 1992, Sedova et al., 1992; Pecho et al., 1993; Viberg et al., 1997; Kawecki et al., 2000; Rubinskiene et al., 2002; Cacace et al., 2003; Bagger-Jorgensen, 2004; Stoyanova, 2005; Siksnianas et al., 2006). Early beginning of fruit-bearing, high and regular yields provide quick return of inputs, additional employment and incomes for the population (Boycheva, 1999; Kawecki et al., 1993; Madry et al., 2000). Therefore, fruit production needs new high-yielding varieties adapted to unstable climatic conditions and meeting most fully the contemporary requirements. This necessitates quick renewal and enrichment of variety structure, through selected Bulgarian and introduced varieties.

The objective of this study was to follow the growth and fruit-bearing of new introduced cultivars of black and red currant and their suitability for cultivation under fore-mountain conditions of the Central Balkan Mountains.

Material and Methods

The field trial was carried out during the 2002-2007 period in a plantation established under the Bulgarian-German project FAMAD. The plants were planted by the trench method at planting distance of 2.50/0.80 m. The conditions of cultivation were non-irrigated. Inter-row spacings were sodded and row band was maintained in black fallow. Every year the black fallow was mulched with the mown grass from the inter-row spacings.

The following characteristics were observed:

- Phenological calendar: beginning of bud opening; early flowering; full flowering; late flowering; ripening; end of vegetation.
- Vegetative characteristics: bush height; bush diameter (perpendicularly to inter-row spacing and along the row); total one-year growth per bush.
- Reproductive characteristics: yield per bush, average weight of one fruit; average fruit number per bunch.
- Data were processed by the variance-statistical method of Lidanski, 1988.

Results and Discussion

The observed cultivars of black currant began vegetation from the second half of March till the beginning of April (Figure 1 – phenogram).

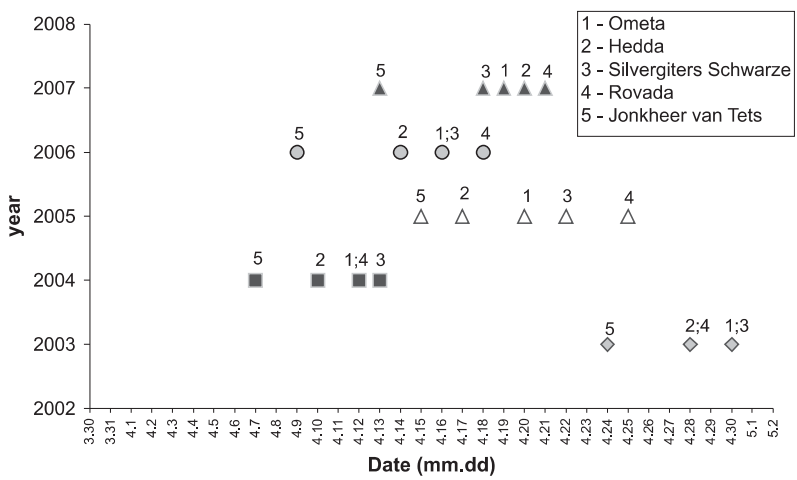

Figure 1. Beginning of flowering of the studied cultivars of black and red currant (2003 – 2007)

Cultivar 'Hedda' was the first to begin development, only in 2007 it was left behind by cultivar 'Ometa'. The flowering took place in the second half of April and ended till mid-May. Most often it lasted for about three weeks. In 2003 and 2004 the flowering ended for two weeks due to sharp temperature increases in late April caused by hot Sahara winds.

The studied varieties of black currant ripened till the beginning of July (Figure 2). Cultivar 'Hedda' was earlier ripening and the other cultivars ripened a little later and almost simultaneously.

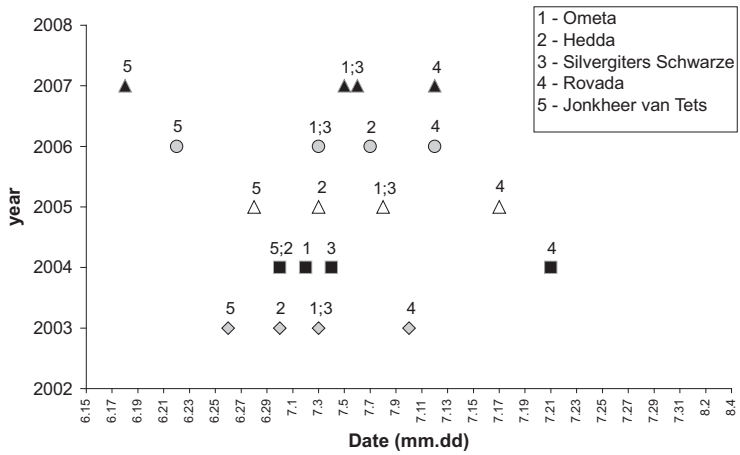

Figure 2. Fruit ripening of the studied cultivars of black and red currant (2003-2007)

Cultivar 'Jonkheer van Tets' had the earliest phenological stages among the red currant cultivars (Figure 1). Its fruit ripening was also earlier near the end of June and that of cultivar 'Rovada' up to three weeks later (Figure 2).

Cultivar 'Hedda' had the shortest vegetation among the studied cultivars – its leaf fall occurred 17 to 50 days, but always varied within a wide range of time, before 'Ometa' and 'Silvergieters Schwarze' that had the longest one. In some years their leaf fall was in December (8.12.2004). The growing season duration of red currants was also cultivar conditioned. It was shorter for the early cultivar 'Jonkheer van Tets' – till 18 November and longer for the late-ripening cultivar 'Rovada' – till 2 December.

Soil-climatic conditions and technologies for cultivation are also of substantial importance to vegetative activities of the plants, in addition to genetic traits. The cultivars 'Ometa' and 'Silvergieters Schwarze' formed the tallest bushes and cultivar 'Ometa' the widest ones (Tables 1, 2 and 3). The bushes of cultivar 'Hedda' had the smallest dimensions and the planting distances applied in our trial were great for it. Both characteristics had significant differences. The red currant cultivar 'Rovada' was superior to 'Jonkheer van Tets' in all three characteristics ($p<0.05$) (Tables 1, 2 and 3).

The black currant cultivars had significant differences also in total one-year growth considered as an average from a five-year period, the values of which were parallel to their bush dimensions – the greatest for cultivars 'Ometa' and 'Silvergieters Schwarze' and the smallest for 'Jonkheer van Tets' (Figure 3).

One of the most important economic indicators of a cultivar is the yield obtained from it. It is directly related to genetic traits of the cultivar, method of cultivation and climatic conditions during vegetation.

During the studied period, cultivar 'Ometa' was distinguished for the highest average yield – 1.59 kg per bush and cultivar 'Hedda' for the lowest one – 0.53 kg (Figure 3).

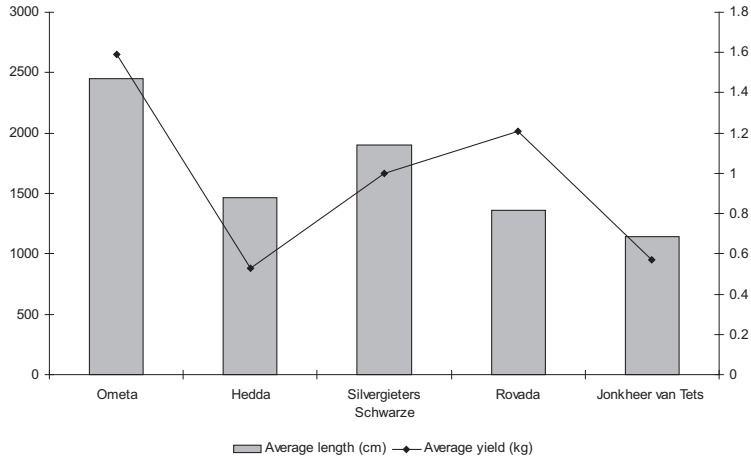

Figure 3. Average yield (kg/bush) and average length of one-year growth (cm) for the period (2002-2007)

The differences were mathematically significant ($p<0.05$). The studied cultivars gave highest yields in 2005 when the plants were in a period of full fruit-bearing and annual rainfall amount reached to 1394 ml/m^2. In red currants the maximum yield was achieved by cultivar 'Rovada' in 2004 – 2.18 kg/bush (Figure 3). During the studied period this cultivar had an average yield of 1.21 kg per bush and that of 'Jonkheer van Tets' was twice lower – 0.57 kg/bush. The differences were not always significant. During the five years of study there was a tendency to alternative fruit-bearing for cultivar 'Rovada'.

Parallel examination of the average values of yield and one-year growth gave an appraisal for productivity of fruiting wood (Figure 3). It was highest in cultivar 'Rovada' where a yield of 1.21 kg was obtained at a total growth of 1360 cm. This represented approximately 1g fruits per centimeter growth. In spite of the higher average yield of cultivar 'Ometa' – 1.59 kg/bush, its wood productivity was relatively lower – 0.65 g fruit per 1 cm growth. The cultivars 'Silvergieters Schwarze' and 'Jonkheer van Tets' showed optimum loading with about 0.5 g per 1 cm growth. In both black and red currant there was very pronounced correlation relationship of these two characteristics.

The average fruit mass was almost the same for all three cultivars of black currant (Table 4). It was insignificantly greater for cultivar 'Silvergieters Schwarze' – 0.91 g. The concrete meteorological conditions in the different years also influenced the size. The fruits had the highest mass in 2004 when they reached up to values of 1.21 g. Probably this was due to the great rainfall amount in June – 133.5 l/m^2 when the fruits became larger. The fruit mass of red currant cultivars varied to a smaller extent (Table 4).

The fruit number in the bunches was cultivar conditioned and relatively constant.

It was greatest in cultivars 'Ometa' – 6.83 and 'Silvergieters Schwarze' – 6.75 and considerably smaller for 'Hedda' – 4.46 (Table 4). 'Rovada' was distinguished from the other studied cultivars for the highest stable number of fruits per bunch and for the relatively equalized average weight in the different years (Table 4). Its bunches were long, having a cylindrical shape and regularly arranged fruits.

Conclusions

On the basis of the field trials carried out with newly introduced cultivars of black and red currant under the soil-climatic conditions of the Troyan region the following conclusions can be made:

- The black currant cultivar 'Hedda' was with a shorter growing season. It was relatively lower-yielding, had the weakest growth and it was possible to decrease its planting distances in the inter-row spacing and to increase the number of plants up to 5500/ha. 'Ometa' is a vigourously growing black currant cultivar distinguished for high and stable yields – 1.59 kg/bush.
- The number of bushes in 1 ha for the vigorously growing cultivars Ometa and Silvergiters Schwarze could be decreased to 4000.
- The mass of the black currant fruits varied more strongly in the different years depending on climatic conditions and that of the red currants remained relatively stable.
- Among the red currants, cultivar 'Rovada' had relatively constant fruit mass, ripened later and was higher-yielding than cultivar 'Jonkheer van Tets'. The latter ripened about three weeks earlier than cultivar 'Rovada', had a looser bunch with less fruits in it.
- Some yield stability was found in the fruit-bearing of the more fruitful cultivars of black currant ('Ometa' and 'Silvergiters Schwarze'), while for the red currants in cultivar Rovada there was a tendency to alternative fruit-bearing.
- The shown optimum parameters of growth and fruit-bearing characterized the newly introduced cultivars 'Ometa', 'Hedda' and 'Rovada' as suitable for cultivation and harvesting in the Troyan region.

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Table 1. Bush height of black and red currant cultivars (cm) (2002-2007)

Characteristics	'Ometa'	'Hedda'	'Silvergieters Schwarze'	'Rovada'	'Jonkheer van Tets'
2002					
M ± m	111.11 ± 2.61	83.11 ± 2.28	109.44 ± 2.19	112.60 ± 3.5	106.70 ± 3.0
$LSD_{0.05}$	6.9			ns	
2003					
M±m	122.11 ± 3.12	92.89 ± 2.33	121.33 ± 3.81	121.44 ± 3.2	121.56 ± 2.6
$LSD_{0.05}$	9.2			ns	
2004					
M±m	135.56 ± 2.29	105.44 ± 1.89	143.22 ± 4.27	128.89 ± 2.94	119.56 ± 5.17
$LSD_{0.05}$	8.8			ns	
2005					
M±m	159.56 ± 4.51	130.33 ± 2.19	158.89 ± 3.43	131.44 ± 3.25	118.67 ± 2.80
$LSD_{0.05}$	10.2			9.1	
2006					
M±m	154.89 ± 2.82	124.33 ± 3.21	148.33 ± 4.29	95.00 ± 2.91	75.00 ± 3.40
$LSD_{0.05}$	10.2			9.5	
2007					
M±m	158.67 ± 3.06	125.11 ± 3.43	160.00 ± 1.96	125.11 ± 2.00	114.44 ± 2.65
$LSD_{0.05}$	8.4			7.0	
Average	140.32	110.20	140.20	119.08	109.32

Table 2. Bush width towards the inter-row spacing in black and red currant cultivars (cm) (2002-2007)

Characteristics	'Ometa'	'Hedda'	'Silvergieters Schwarze'	'Rovada'	'Jonkheer van Tets'
2002					
M ± m	112.78 ± 3.91	81.11 ± 3.83	109.56 ± 5.80	94.89 ± 4.86	67.44 ± 3.49
$LSD_{0.05}$	13.4			12.7	
2003					
M±m	118.44 ± 6.38	88.56 ± 2.99	104.00 ± 6.01	118.33 ± 7.67	88.00 ± 5.17
$LSD_{0.05}$	15.6			19.6	
2004					
M±m	166.22 ± 7.73	109.11 ± 2.62	134.56 ± 7.65	123.89 ± 4.26	88.00 ± 5.17
$LSD_{0.05}$	18.8			14.2	
2005					
M±m	177.22 ± 4.37	108.44 ± 3.84	146.22 ± 8.89	122.67 ± 2.80	91.56 ± 4.53
$LSD_{0.05}$	17.9			11.3	
2006					
M±m	114.44 ± 4.44	94.89 ± 4.52	99.22 ± 6.66	95.00 ± 2.91	75.00 ± 3.40
$LSD_{0.05}$	15.5			9.5	
2007					
M±m	145 ± 8.28	98.22 ± 4.00	132.33 ± 8.34	118.78 ± 4.27	92.78 ± 2.33
$LSD_{0.05}$	20.9			10.3	
Average	139.02	96.72	120.98	112.26	83.80

Table 3. Bush width towards the row in black and red currant cultivars (cm) (2002-2007)

Characteristics	'Ometa'	'Hedda'	'Silvergieters Schwarze'	'Rovada'	'Jonkheer van Tets'
2002					
M ± m	96.56 ± 6.69	77.44 ± 2.61	84.67 ± 5.31	82.67 ± 4.34	74.00 ± 3.87
$LSD_{0.05}$	15.0			12.3	
2003					
M±m	113.56 ± 5.61	84.89 ± 2.50	89.56 ± 4.88	105.00 ± 4.94	81.67 ± 5.01
$LSD_{0.05}$	13.2			14.9	
2004					
M±m	133.67 ± 5.64	96.89 ± 3.81	95.11 ± 3.97	104.11 ± 3.29	87.22 ± 5.98
$LSD_{0.05}$	13.3			14.5	
2005					
M±m	136.33 ± 8.03	96.00 ± 3.67	109.67 ± 7.49	98.67 ± 3.02	85.78 ± 3.50
$LSD_{0.05}$	19.5			9.8	
2006					
M±m	83.33 ± 4.84	82.67 ± 6.74	90.67 ± 3.32	73.11 ± 2.58	70.22 ± 4.23
$LSD_{0.05}$	15.1			10.5	
2007					
M±m	115.11 ± 6.48	92.33 ± 7.97	96.78 ± 2.69	87.78 ± 4.67	82.44 ± 4.03
$LSD_{0.05}$	17.9			n.s	
Average	113.09	88.37	94.41	91.89	80.22

Table 4. Average weight and number of fruits per bunch for the period (2003-2007)

Period / Cultivars	2003	2004	2005	2006	2007	Average	$LSD_{0.05}$
Average weight of 1 fruit							
'Ometa'	0.69	1.09	1.08	0.69	0.86	0.88	
'Hedda'	0.85	1.21	0.99	0.58	0.79	0.88	P < 0.05
'Silvergiters Schwarze'	0.68	1.20	0.96	0.76	0.96	0.91	
'Rovada'	0.51	0.50	0.64	0.33	0.47	0.49	P < 0.05
'Jonkheer van Tets'	0.57	0.52	0.46	0.50	0.48	0.51	
Average number of fruits in 1 bunch							
'Ometa'	11.7	4.8	5.5	5.48	6.67	6.83	
'Hedda'	6.7	2.7	3.4	4.04	5.44	4.46	P < 0.05
'Silvergiters Schwarze'	12.3	4.2	5.3	5.19	6.78	6.75	
'Rovada'	7.58	7.3	8.5	7.0	6.89	7.45	P < 0.05
'Jonkheer van Tets'	5.4	4.2	4.8	4.44	5.07	4.78	

FRUIT QUALITY ASSESSMENT OF APPLE CULTIVARS

Laila IKASE, Dalija SEGLIŅA

Latvia State Institute of Fruit-Growing, Graudu 1, Dobele, LV-3701, Latvia
e-mail: laila.ikase@lvai.lv; dalija.seglina@lvai.lv

Abstract

Fruit quality is among the main factors of the success of a cultivar on the market. As development of modern apple growing in Latvia started only about 10 years ago, the variety assortment is still in the making process. A market-oriented project for evaluating the consumer acceptance of apple cultivars and the changes of their inner quality was done in 2005-2007 by the researchers of the Latvia State Institute of Fruit-Growing, with the aim to improve the recommended assortment of apples for commercial growing. Apple cultivars more widely grown in Latvia were included in the project, along with some new ones, in total 24 cultivars. Consumer polls were made at one supermarket and several exhibitions, using line-scale sensory evaluation (size, colour, flavour, firmness, juiciness) and questionnaires. The fruits were also analyzed for their content of Brix, titrable acids and firmness after the storage period. Apple cultivars were also evaluated by open taste panels at LSIFG (attractivity and flavour, in points 1-10).

In total 833 consumer responses were received. Most of the evaluated apple cultivars received good consumer evaluation, yet some ('Tellissaare', 'Konfetnoe') had lower estimation. Convincing leaders in the group of late cultivars were 'Auksis' and 'Saltanat', yet the latter has rather short period of best quality. No leading cultivars could be named in the group of early and very late ones, which shows the necessity to look for new cultivars in these groups. Some candidates for such cultivars were selected by taste panels at LSIFG.

Key words: apple, commercial cultivars, consumer evaluation, Latvia

Introduction

Fruit quality is among the main factors of the success of a cultivar on the market. Quality is usually interpreted as all the characteristics that lead the consumer to be satisfied with the product (Harker et al., 2003). For apple the most frequently named traits are size, shape, colour, firmness, crispness, juiciness, sweetness, acidity, flavour. Consumer tests of eating quality have become an essential part of breeding and introduction of new cultivars, for example, in the European HiDRAS project (Gianfrancesci and Soglio, 2004; Leumann et al., 2005; Kellerhals and Eigenmann, 2006; Jesionkowska et al., 2006). While there is no doubt that fruit quality is one of the deciding factors in consumer choice, the consumer preferences vary significantly from country to country (Cliff et al., 2002; Sansavini et al., 2004).

As development of modern apple growing in Latvia started only about 10 years ago, the cultivar assortment is still in the making process. The assortment of cultivars is large, over 20 cultivars are recommended for planting in commercial orchards, the 10 most popular each occupying only 2 to 8% of new orchard area, which presents difficulties for the marketing of produce (Skrivele, 2004). The choice of recommended cultivars was made by researchers and fruit growers, but wider studies of their consumer acceptance have not been performed so far.

The aim of our investigation was to evaluate the consumer acceptance of Latvian-

grown apple cultivars, the factors determining acceptance of apples and to select cultivars with the best consumer evaluation.

Materials and methods

A market-oriented project for evaluating the consumer acceptance of apple cultivars and the changes of their inner quality was performed in 2005-2007 by the researchers of the Latvia State Institute of Fruit-Growing (LSIFG), with the aim to improve the recommended assortment of apples for commercial growing.

Apple cultivars more widely grown in Latvia were included in the project, along with some new ones, in total 24 cultivars and promising selections. These were: in the group of early cultivars – 'Agra' (new Latvian cv.), 'Discovery', 'Doch Melbi', 'Baltais Dzidrais' ('White Transparent'), 'Konfetnoe', red-fruited clone of 'Korobovka' ('Cukuriņš'), 'Melba' and selection BM 55734 (Balsgard, Sweden); in the group of midseason cultivars – 'Korichnoe Novoe', 'Kovalenkovskoe', 'Merrigold', 'Tiina'; in the group of late cultivars – 'Auksis', 'Antei', 'Iedzenu', 'Lobo', 'Rubin' (Kazakhstan cv.), 'Saltanat', 'Tellissaare'; in the group of very late cultivars – 'Ausma' (new cultivar from LSIFG), 'Belorusskoe Malinovoe', 'Sinap Orlovskii', 'Spartan' and 'Zarya Alatau'.

Consumer polls were made at one supermarket and several exhibitions, using line-scale (ISO 4142:1987 Sensory Analysis-Methodology-Evaluation of frood products by using scales) descriptive sensory evaluation of size, colour, flavour, firmness, juiciness. Whole boxes of standard quality fruits were used for the rating, and slices of the same fruits were used for tasting.

Questionnaires were also used to group the respondents by sex, age and education. To find out general preferences in choice of apples (size, colour type, flavour type, firmness, juiciness) the following questions were asked:

- Which of the following is important when you buy fruits – known seller, known cultivar, something new, other.
- Which of the following are important in your choice of fruits (can be several answers) – packing, fruit size, colour (which: yellow, red, bicolor), taste, price, other.
- What traits of fruit taste do you like – crisp and firm, juicy, soft, sweet, subacid, tart, other.

The fruits of the above mentioned cultivars were analyzed for their content of soluble solids (brix), titrable acids and firmness after the storage period. The analyses were performed at the same time as the consumer poll and on the same lot of fruits. The content of soluble solids was determined by "Atago" digital refractometer SMART-1, scale 1 to 50%. The total acids were determined by using 0.1n NaOH, 1% phenolphthalein and accessories – distilled water, magnetic mixer MS 3000, electric bath. Flesh firmness was determined by "Atago" hand penetrometer FT 327 (1cm^2), scale 0.2 to 12.7 kg/cm^2.

Apple cultivars were also evaluated by open taste panels consisting of about 10 persons, in 2004-2007 at LSIFG. Whole unpeeled fruits and slices were presented to panel members on platters (6 to 10 typical fruits of cultivar), to rate attractivity and flavour, in points 1 to 10. The taste panels included new promising cultivars and some widely grown ones as standard (ST).

The data of the consumer poll and the taste panels at LSIFG were statistically processed. Analysis of variance was performed using SPSS 11.0 for Windows. Significant differences between means were determined at level of $p<0.05$.

Results and discussion

Consumer polls. In total 833 consumer responses were received. The most active respondents were women (76%) and persons with higher education (62%), the age groups were represented almost equally. Answers showed a wide diversity in preferences. Still, most (64-73% depending on group) preferred juicy apples, and only 19-50% would like crisp and firm apples – the highest preference (50%) here was registered among persons with primary education, which includes mostly children and teenagers. That this group of consumers has different preferences from others has been shown also in other studies (Kuhn and Thybo, 2001; Jesionkowska et al., 2006). Only 5-8% (depending on group) answered that they prefer soft apples. Age groups 35-50 and 51-65 preferred subacid fruits (75% and 82%, correspondingly) while respondents below 35 and above 65 years chose sweet fruits. Yet it became clear in discussions with respondents that by "sweet" the majority understand fruits in which sweetness dominates over acidity, not those almost lacking acidity. No distinct preferences were found for fruit appearance (size, colour). The consumers seem also rather conservative in their choice, about 50% respondents would prefer a known cultivar when buying. Yet, if offered to try a new cultivar, 50% (age over 51) to 100% (age below 35) agreed.

Line-scale rating. Variance analysis found highly significant ($p = 0.000$ to 0.002) differences between the evaluated cultivars. Most of the evaluated apple cultivars received good consumer evaluation, yet some ('Tellissaare', 'Konfetnoe') had lower estimation (Figures 1 to 4).

Convincing leaders in the group of late cultivars were 'Auksis' and 'Saltanat' (Figure 3); the latter was rated the highest yet has rather short period of best quality. These cultivars are characterized by bright over-colour and smooth, uniform fruits, rather high content of brix (13.21% for 'Auksis' and 14.17 % for 'Saltanat'), medium acidity (0.48% for both cvs.). The firmness of their fruits is medium ('Auksis', 5.31 kg cm^{-2}) or over medium ('Saltanat', 7.26 kg cm^{-2}) as shown in Figures 5 to 7. They were rated as very juicy ('Saltanat') or juicy ('Auksis') by the consumers.

Both 'Auksis' and 'Saltanat' may also be ranged among midseason cultivars, as their eating maturity starts at picking time. This way, they heavily compete with "real" midseason cultivars with shorter storage, among which 'Merrigold' has received the best general rating. Yet, the fruits of this cultivar are too soft for marketing (firmness 4.5 kg cm^{-2}).

It must be noted that in the group of early cultivars the red clone of 'Korobovka' received the highest ratings, in spite of typically small fruit size (Figure 1). This may be because this cultivar is very well known and all cultivars were tasted under their real names. No other leading cultivars could be named in the groups of early and very late cultivars, which showed the necessity to look for new varieties in these groups.

Firmness, soluble solids and acids content. Among the early cultivars, only 'Doch Melbi' had high fruit firmness, over 8 kg cm^{-2} (Figure 5). Other cultivars with firm fruits

were late ripening 'Iedzenu' and 'Tellissaare', but they did not receive good consumer rating, possibly because of lower juiciness (Figure 3). The average flesh firmness of 24 cultivars in our study was 6.15 kg cm^{-2}, and few had firmness outside the range of 5-7 kg cm^{-2}. The majority of cultivars with the best consumer rating had medium firm or soft fruits, and only some – over medium firmness. This corresponds with the argument of Sansavini et al. (2004) that crispness which is a desirable trait must not be confused with firmness – too firm fruits may have chewy, hard flesh unacceptable to consumers, especially older people. Also, in a consumer study in Sweden no distinct preference was found for firmer and less firm apples among the consumers (Jönsson, 2004). It may be presumed that consumers in Northern Europe are more used to soft fruits and associate them with good eating quality. While in the answers about general preferences in our poll (see above) only a few said they prefer soft apples, the good consumer rating of some soft-fleshed cultivars shows that personal understanding of soft/firm may differ. Joint firmness-crispness character was evaluated in the line-scale rating of cultivars in our study, because it was decided to minimize the number of questions to consumers, but in further investigations it will be necessary to split out the trait of crispness.

Cultivar with the highest soluble solids content was the red clone of 'Korobovka' (16.96 Brix %), which also was rated highly by consumers. The brix content of other cultivars ranged from 12.05 ('White Transparent') to 14.50% ('Antei') as shown in Figure 6.

The acidity of the evaluated cultivars varied significantly (Figure 7). 'Tiina' had the lowest content (0.12%), which classifies as insipid. Still, it was liked by part of the consumers and did not receive the lowest average flavour rating (Figure 2). The most acidic were the fruits of early cultivars 'White Transparent' and 'Doch Melbi' and very late cultivar 'Sinap Orlovskii'. The acids content of cultivars with the best consumer acceptance was from 0.43 (red 'Korobovka', 'Merrigold') to 0.61% ('Saltanat').

Taste panels. Some new cultivars with better fruit rating were selected by open taste panels at LSIFG (Table 1). In the group of medium ripening cultivars 'Amorosa', 'Greensleeves' and 'Sawa' Vf, in the group of medium-late cultivars 'Bohemia', 'Dace' Vf (new cultivar of LSIFG) and 'Pamyat Semakinu', in the group of late cultivars 'Alesya' were ones which surpassed commercially grown cultivars both by fruit attractivity and flavour. Of these, 'Pamyat Semakinu', 'Dace' Vf and 'Alesya' have shown also good winter-hardiness in the local climate, while the others may be risky to grow in Latvia except in the most favourable conditions. These three cultivars will be included in further trials.

Conclusions

1. Different consumer groups had different preferences for fruit quality. Almost all consumers preferred juicy fruits, but firm and crisp apples were not distinctly popular among Latvian consumers.
2. Not all commercially grown apple cultivars received good consumer evaluation. There is need to find better cultivars, especially in the groups of early and very late cultivars.
3. The most widely grown cultivar 'Auksis', as well as 'Saltanat', both in the group of late cultivars, received high consumer evaluation. Their consumption maturity starts early and overlaps with midseason cultivars, too.

4. In the group of early cultivars the red clone of 'Korobovka' was rated the highest in spite of very small fruit size. It had also the highest soluble solids content (16.96 Brix %).
5. The acids content of cultivars with the best consumer acceptance was from 0.43 to 0.61%.
6. The majority of cultivars with the best consumer rating had medium firm or soft fruits, and only some – over medium firmness.
7. In taste panels at LSIFG the new cultivars 'Dace' Vf, 'Pamyat Semakinu' and 'Alesya' were selected as promising for their fruit quality.

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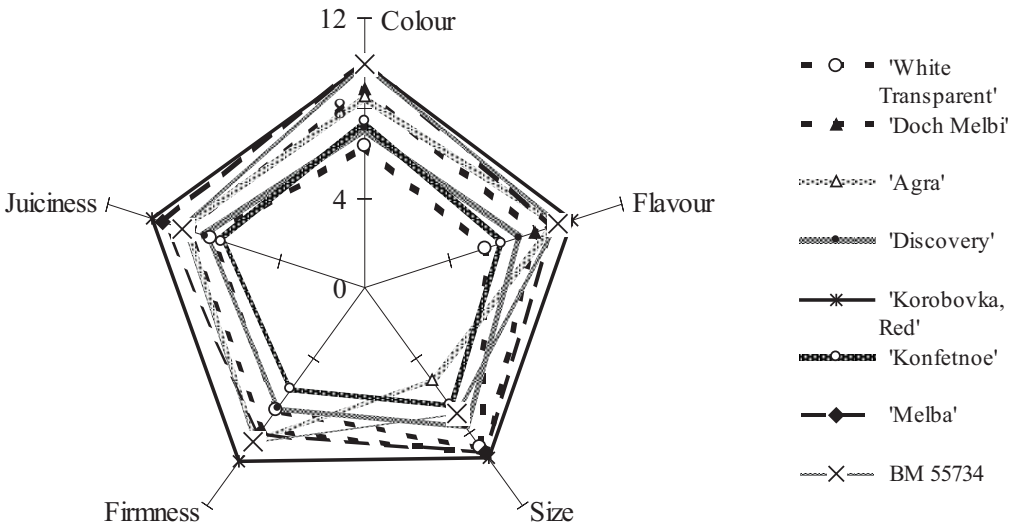

Figure 1. Line-scale diagram of apple sensory evaluation (early cultivars)

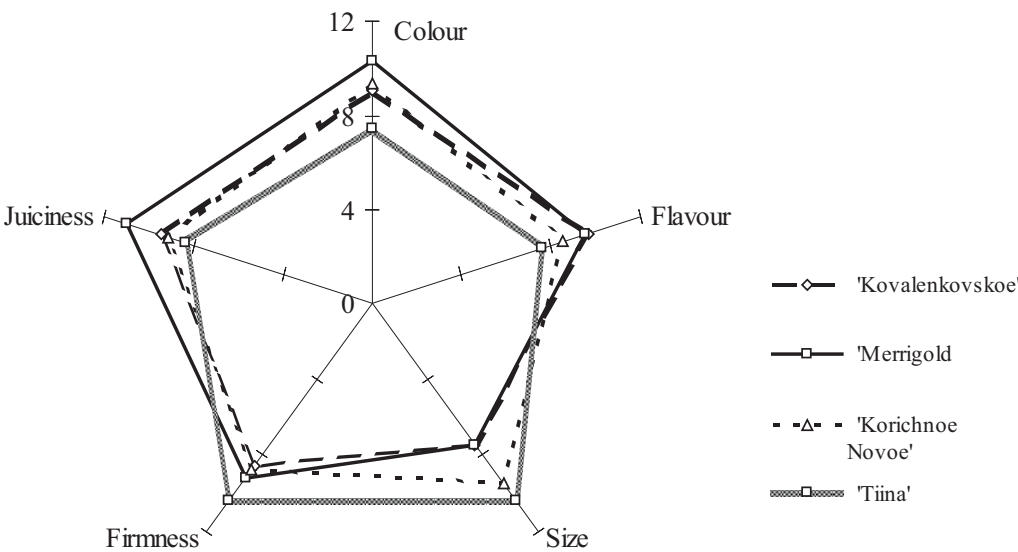

Figure 2. Line-scale diagram of apple sensory evaluation (midseason cultivars)

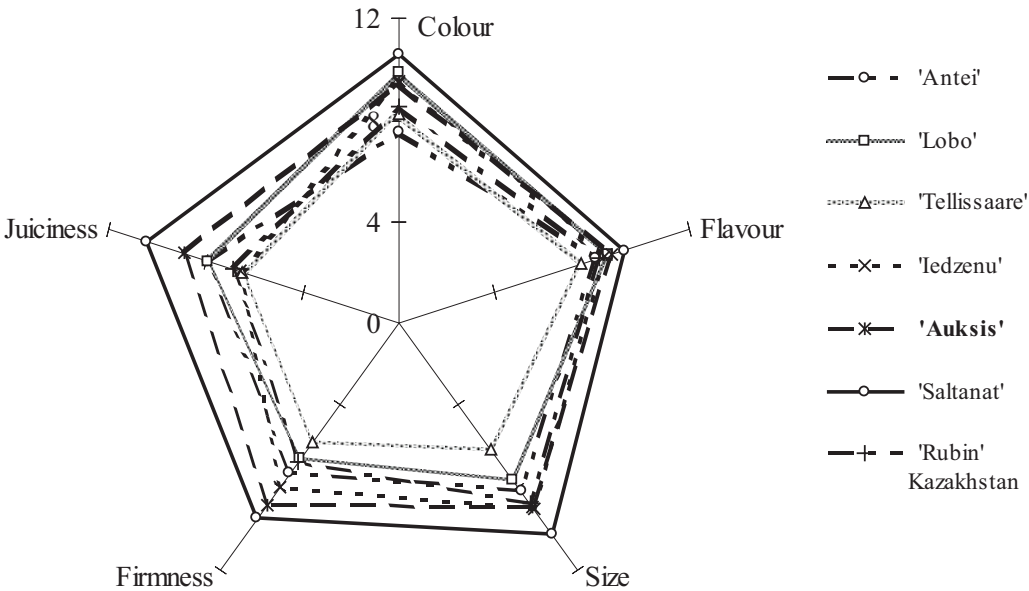

Figure 3. Line-scale diagram of apple sensory evaluation (late cultivars)

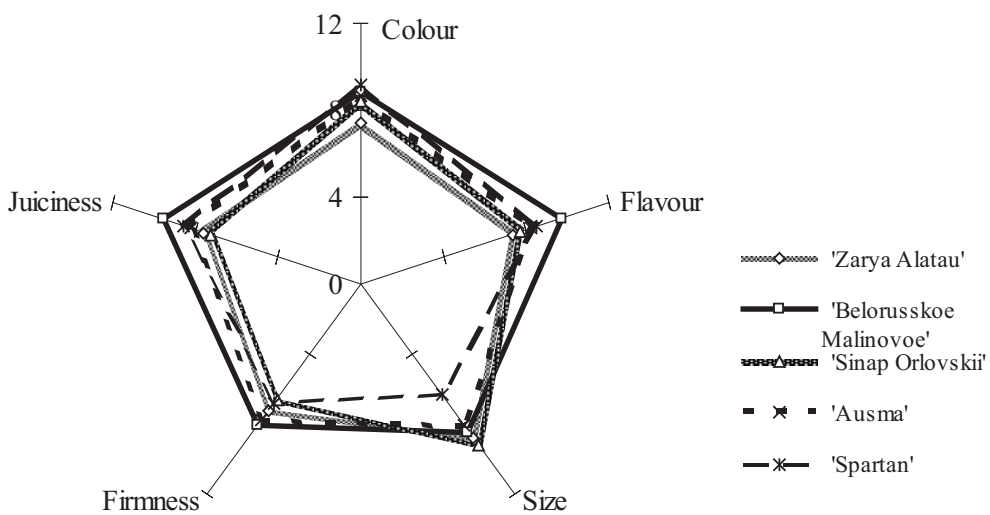

Figure 4. Line-scale diagram of apple sensory evaluation (very late cultivars)

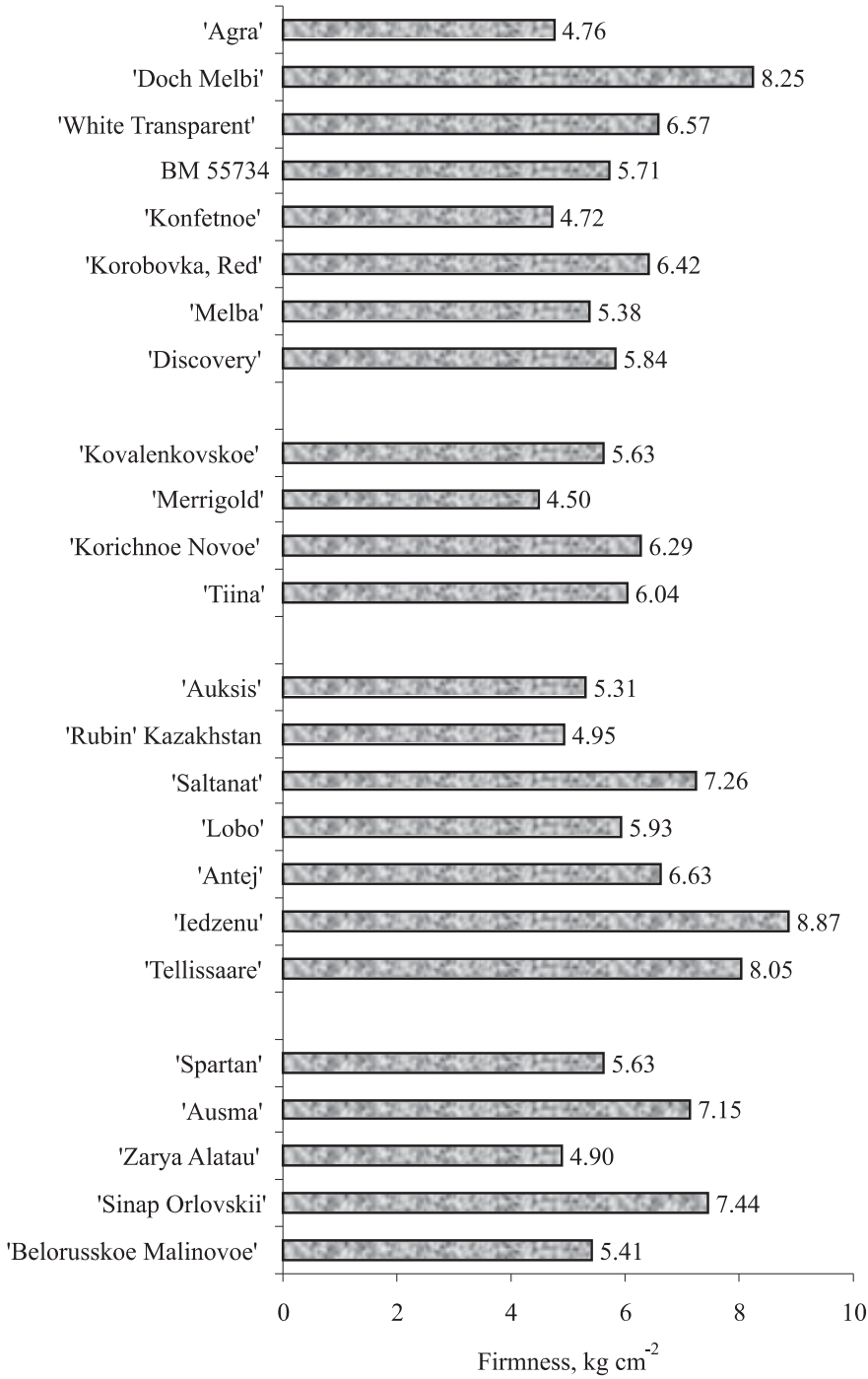

Figure 5. Average flesh firmness of apple cultivars

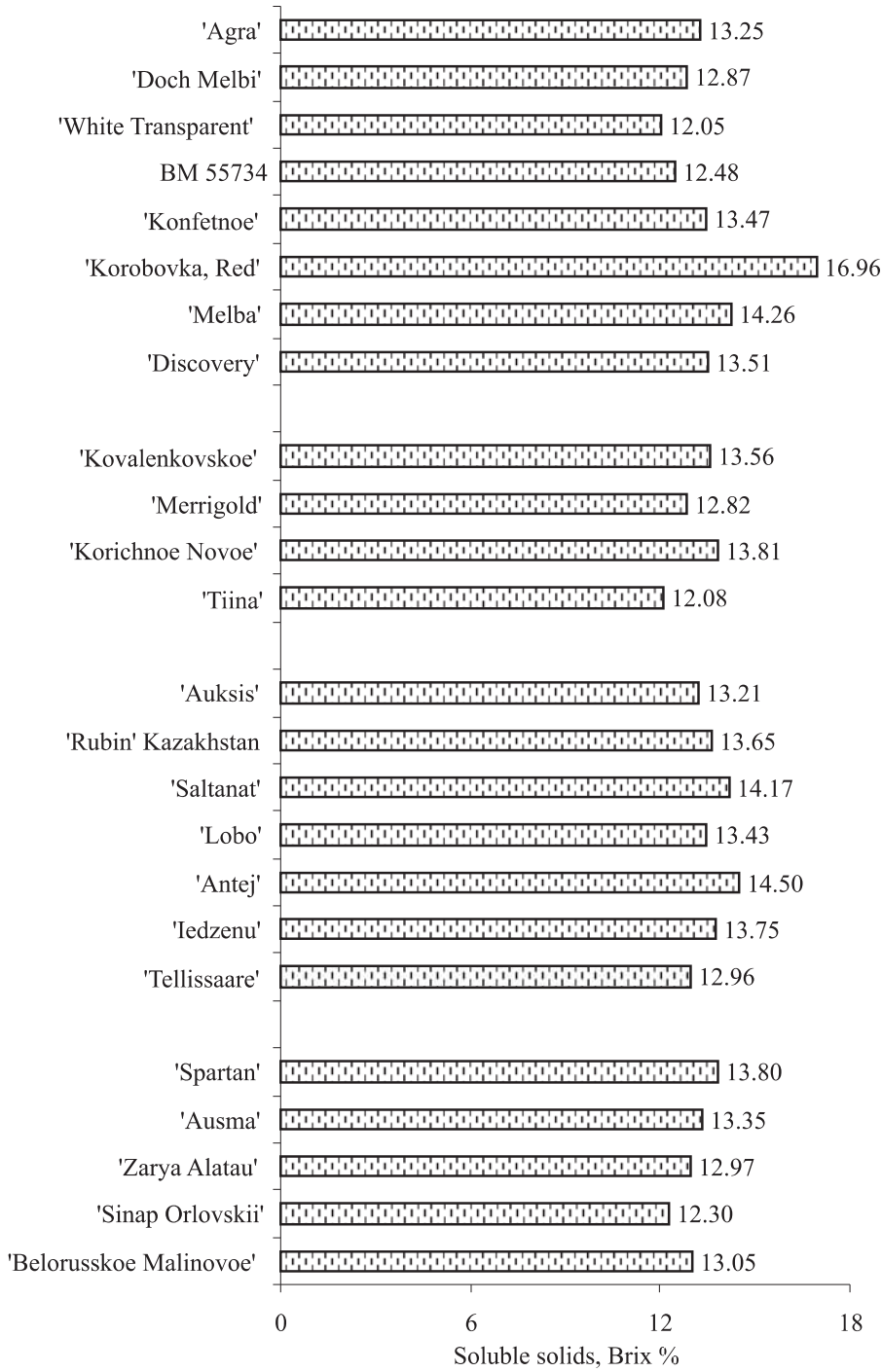

Figure 6. Average soluble solid content of apple cultivars

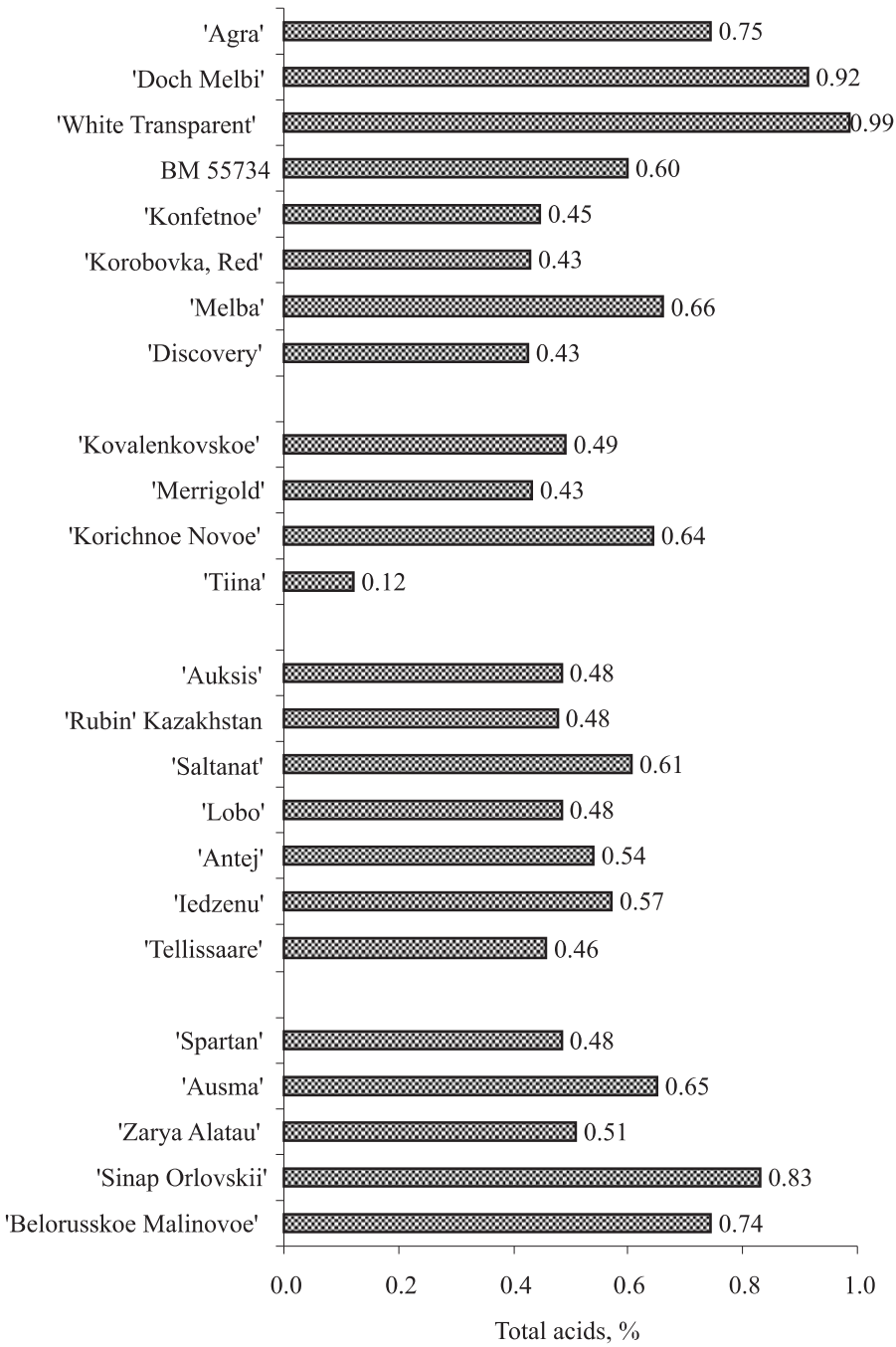

Figure 7. Average total acid content of apple cultivars (2006-2007)

Table 1. Taste panel evaluation of new apple cultivars (average of 2004-2007)

Nr.	Cultivar	Season of consumption	Attractivity		Flavour	
			average	subset	average	subset
1	Roberts Vf	early	7.53	ab	7.33	abc
2	Delbard Estivale	early-medium	6.50	a	6.90	abc
3	Jamba	early-medium	7.60	ab	6.30	ab
4	Gita Vf	medium	7.90	ab	**7.65**	bc
5	Liivika	medium	7.40	ab	**7.67**	bc
6	Kurnakovskoe Vf	medium	7.50	ab	6.10	a
7	Krista	medium	7.90	ab	6.75	abc
8	Zirochka	medium	7.73	ab	7.20	abc
9	Greensleeves	medium	**8.40**	b	**7.60**	bc
10	Sawa Vf	medium	**8.27**	b	**7.73**	c
11	Jester	medium	**8.10**	b	7.20	abc
12	Dzintariņš	medium	7.07	ab	7.20	abc
13	Amorosa	medium	**8.13**	b	**8.13**	c
14	Auksis (ST)	medium-late	7.90	ab	**7.65**	bc
15	Dace Vf	medium-late	**8.05**	b	**7.65**	bc
16	Pamyat Semakinu	medium-late	**8.20**	b	**7.60**	bc
17	Ornament	medium-late	7.27	ab	7.20	abc
18	Edite Vf	medium-late	8.00	ab	7.20	abc
19	Elegiya (Ukraine)	medium-late	7.80	ab	**7.70**	bc
20	Bohemia	medium-late	**8.20**	b	**8.15**	c
21	Honeycrisp	late	7.80	ab	7.20	abc
22	Ligita	late	7.27	ab	7.47	abc
23	Olga	late	7.53	ab	**7.53**	bc
24	Alesya	late-very late	**8.20**	b	**7.67**	bc
25	Ausma	late-very late	**8.13**	b	7.27	abc
26	Kent	late-very late	7.67	ab	6.80	abc
27	Angold	late-very late	8.00	ab	7.50	abc
28	Alwa	very late	7.07	ab	6.93	abc
29	Belorusskoe Malinovoe (ST)	very late	7.60	ab	7.33	abc
30	Lodel	very late	7.80	ab	6.90	abc
P-values: cultivar/attractivity=0.004; cultivar/flavour=0.000 (significant)						
P-values: year/attractivity=0.149; year/flavour=0.610 (not significant)						

Note: Cultivars are ranged in the order of ripening for consumption

GROWTH AND YIELDING OF 16 SOUR CHERRY CULTIVARS IN ECOLOGICAL ORCHARD CONDITIONS

Agnieszka GŁOWACKA, Elżbieta ROZPARA, Zygmunt S. GRZYB

Institute of Pomology and Floriculture, Skierniewice
email: Agnieszka.Głowacka@insad.pl

Abstract

The experiment was established in the spring of 2004 in the Experimental Ecological Orchard in Nowy Dwór (central Poland). The suitability of sour cherry trees for organic production was assessed in terms of tree growth, yielding, fruit quality and tree health status. Sixteen cultivars were evaluated: 'Oblacinska', 'Lucyna', 'Wanda', 'Stevnsbaer', 'Elmer', 'Pamiat Wawilowa', 'Wlodzimierska', 'Naumburger', 'Slupia Nadbrzeżna', W 1/02, W 2/02, W 7/02, W 8/02, W 9/02, W 10/02 and W 12/02. The trees grafted on *Prunus mahaleb* seedlings were planted at a spacing of 4.5x 2.5 m, in four replications with three trees per plot, and were trained in the spindle form. Plant protection was based on cuprum and sulfur. The trees were irrigated. Preliminary results show that the most interesting sour cherry cultivars for ecological orchards are the hybrid W 12/02, and also 'Stevnsbaer', 'Słupia Nadbrzeżna' and W 10/02. The cultivar 'Elmer' is not recommended for ecological fruit production.

Key words: fruit quality, tree growth, tree health, yield

Introduction

The sour cherry is an important species in fruit growing in Poland. In terms of both the number of trees and the size of fruit production, the species is in second place after the apple (GUS, 2008). Sour cherry fruit have an exceptionally high dietary value because they contain considerable amounts of sugars (8–10%), organic acids (1.5–2%), pectins, tannins, carotenes, vitamins (C, B, PP and folic acid), and also minerals that are of importance to human health, such as copper, iron, magnesium, phosphorus, calcium and potassium (Sitarek, 2002)..They facilitate binding and excretion of toxins from the body, and also reduce the level of cholesterol in the blood. Moreover, results of research carried out in Hungary and Germany have shown that sour cherry fruits contain large amounts of anthocyanins, flavonoids, melatonine and other bioactive components referred to as 'phytochemicals', which have anti-inflammatory (fever-reducing) and anticancer effects. Their antioxidant properties are several times higher than those of vitamin C (Veres et al., 2005).

In recent years, the demand for ecological products, including fresh fruit, has been growing. In the ecological method of cultivation, no chemical agents, mineral fertilizers or herbicides are used. The basic tools are agrotechnical treatments and crop rotation. To control pests in ecological orchards use is made of their natural enemies and of natural compounds of mineral and plant origin (Zuber et al., 1997; Caruso et al., 2004). These measures are less effective than synthetic compounds, and do not produce long-lasting effects. Because of the limited possibilities of protecting trees in ecological orchards, it is very important to select cultivars that are characterized by low susceptibility to diseases.

No research work has so far been carried out on the suitability of sour cherry cultivars for ecological cultivation. The establishment by the Institute of Pomology and Floriculture of the first Ecological Orchard in Poland, in Nowy Dwór near Skierniewice in the spring of 2004, had created an opportunity to set up an experiment in which various types of sour cherry trees could be assessed in terms of their suitability for ecological cultivation.

Material and methods

For this experiment, sour cherry cultivars were selected on the basis of observations carried out in 2002–2003 of more than a hundred cultivars in the collection of sour cherry trees in Dąbrowice near Skierniewice. Only those cultivars were chosen which in the integrated production stood out because of their high productivity, good fruit quality and high resistance to fungal diseases, in particular to leaf spot and bitter rot (Grzyb and Rozpara, 2004). Among the selected cultivars there were: 'Stevnsbaer', 'Elmer', 'Pamiat Wawiłowa', 'Włodzimierska', 'Wanda', 'Naumburger', 'Słupia Nadbrzeżna', 'Oblacińska', 'Lucyna', and 7 types of juicing sour cherry denoted by the symbols: W1/02, W2/02, W7/02', 'W8/02, W9/02, W10/02 and W12/02. The sour cherry trees, grafted on *Prunus mahaleb*, were planted in the spring of 2004 at a spacing of 4.5 x 2.5 m, in four replications, with three trees per plot. For the first 2 years, the soil in the orchard was maintained as mechanical fallow; after that, mechanical fallow was left in tree rows while grass, self-sown or sown deliberately, was allowed to grow in the inter-rows. The crowns of the trees have been trained in a spindle-like form. Every year in August, light sanitary and rejuvenating pruning is carried out. To protect the trees, only those agents that are allowed for use in ecological cultivation are used. Since 2005, the trees have been sprayed with copper preparations twice in the season.

In the experiment, tree growth vigour, yielding and fruit quality are studied. Observations are also carried out in relation to vegetation start and finish dates, and tree flowering and fruit ripening times, as well as the incidence of pests and diseases. Preliminary observations indicate that pests and diseases will present the biggest problem in the ecological cultivation of sour cherry.

Results and discussion

Occurrence of diseases

The most frequently occurring diseases in sour cherry orchards include: bacterial canker *(Pseudomonas syringae),* brown rot *(Monilinia laxa, Monilinia fructigena),* leaf spot *(Blumeriella jaapi)*, and bitter rot *(Glomerella cingulata).*

The occurrence of pests and diseases on sour cherry trees was monitored annually. At four different times each season, i.e. in early spring, at the end of May, in August, and in October, the trees were examined to determine the number of areas of gumming – symptoms of bacterial canker. The occurrence of brown rot was assessed by recording for each tree the number of dying flowers and later shoots. Inspections for the presence of leaf spot were carried out every month, from June onwards. For each tree, the percentage of affected leaves and those that had fallen was determined. The extent to which the fruit crop had been affected by bitter rot was assessed after harvest on the basis of a mixed

sample of 100 fruits taken randomly from three trees of a replication.

Bacterial canker did not present much of a problem in this orchard. As yet, symptoms of the disease have not been found on the trees of any of the cultivars under study.

Brown rot occurred only occasionally. In 2006, one or two shoots were found dead, in isolated cases, on the trees of the cultivars: 'Pamiat Wawiłowa', 'Stevnsbaer', 'Włodzimierska', 'Oblacińska', 'Słupia Nadbrzeżna', W9/02 and W12/02; the shoots were cut off on a regular basis. In 2007, the disease practically did not occur. Single dying shoots were found only on the trees of the cultivars 'Oblacińska' and 'Słupia Nadbrzeżna'.

The third disease observed on the sour cherry trees was leaf spot. It constitutes a serious problem in the ecological cultivation of sour cherry. Its symptoms were found on the leaves of the studied sour cherry cultivars every year during the vegetative period. The extent of the symptoms was closely connected with a specific cultivar. The highest infection rate was recorded in 2005 in the cultivars: 'Stevnsbaer', W1/02, 'Wanda', 'Słupia Nadbrzeżna' and 'Włodzimierska'. In 2006–2007, the most susceptible to leaf spot were the cultivars: 'Elmer', W9/02, 'Stevnsbaer', 'Słupia Nadbrzeżna', 'Wanda', 'Naumburger' and W10/02 (Table 1). In 2007, the cultivar denoted by the symbol W7/02 also proved to be susceptible to the disease. The year 2007, however, was different from the previous years because abundant precipitation during the summer had contributed to a fast development of infection, and by the beginning of August trees of the cultivar 'Elmer' had already completely lost their leaves, while the extent of leaf fall in 'Stevnsbaer', W9/02, 'Naumburger' and W7/02 was 90%. At the beginning of September, the only trees that remained well-leaved were those of 'Pamiat Wawiłowa'; some leaves could still be found on the trees of 'Oblacińska' and 'Lucyna'; the other cultivars no longer had any leaves at all. By contrast, during the previous seasons, the trees of most of the cultivars still had their leaves in October. Premature defoliation of sour cherry trees is an undesirable occurrence because it leads to a significant reduction in yield the following year. Moreover, it weakens tree growth and makes trees more susceptible to frost damage.

Occurrence of pests

Among the pests most often found in sour cherry orchards are: the cherry fruit moth *(Argyresthia ephipiella)* and cherry fruit fly *(Rhagoletis cerasi)*; occasionally, we can also find the cherry blackfly *(Myzus cerasi)* and the garden chafer *(Phyllopertha horticola)*.

In our orchard, the trees are young and so far have not produced many fruits; thus it is still too early to make a comprehensive assessment of the occurrence of the cherry fruit moth and the extent of damage inflicted by it in the ecological cultivation of sour cherry. In the current year, the trees flowered abundantly, but late spring frosts caused serious damage to blossoms and made it difficult to assess the occurrence of that pest.

In the years 2005–2007, the presence of the cherry blackfly (aphid) on the sour cherry trees was investigated. The observations were carried out every 2 weeks, from the beginning of May until the last days of August. So far, aphids have not presented much of a problem in the ecological cultivation of sour cherry. In 2005, a small population of

blackflies was observed only on the cultivar 'Oblacińska'; in 2006, single concentrations appeared on the trees of the cultivars: 'Elmer', 'Włodzimierska', 'Pamiat Wawiłowa', 'Oblacińska' and the types: W9/02 W1/02 and W7/02; in 2007, there were no aphids on the sour cherry trees.

Assessment of fruit health status

The sour cherry trees produced fruit for the first time in 2006. The yields, depending on the cultivar, were from 0.2 to 2.8 kg per tree. In 2007, the bearing of fruit was very poor because spring frosts had damaged the blossoms (Table 2).

In the years 2006–2007, the fruits were thoroughly assessed in terms of the extent to which they were affected by cherry fruit fly. In both seasons, the least affected were the fruits of the cultivars 'Stevnsbaer' and 'Słupia Nadbrzeżna', and of the sour cherry types with the symbols: W2/02, 'W12/02', W9/02 and W10/02 (Table 2). No clear relationship could be established between the fruit ripening time and the degree of infestation. It is worth emphasizing that in the year 2007 fruits of the cultivars 'Stevensbaer' and 'W12/02' were completely free from fruit fly larvae. In both years of the experiment, the most affected were the fruits of the cultivar 'Elmer' (more than 40% of the crop).

The percentage of fruits affected by bitter rot was also determined in 2006–2007. The smallest number of decaying fruits was found in sour cherry 'W12/02', 'Stevnsbaer' and 'Słupia Nadbrzeżna', and the largest (almost 50%) in the crops produced by the trees of 'Elmer' and 'Włodzimierska' (Table 2).

Conclusions

On the basis of the observations to date, it can be stated that the biggest problems in the ecological cultivation of sour cherry are presented by: cherry leaf spot, pathogens causing fruit decay, and the cherry fruit fly. The plant protection programme based on the agents allowed for use in ecological orchards does not make it possible to obtain good quality fruit from the trees of all the cultivars included in the experiment. The preliminary results of the observations show that the cultivar 'Elmer' is not suitable for ecological orchards because it is very susceptible to leaf spot and its fruits become severely affected by the cherry fruit fly and bitter rot. On the other hand, sour cherry W12/02 is very promising; it is medium susceptible to leaf spot and produces attractive, large fruits of good quality. In the years 2006–2007, good fruit in terms of quality were also collected from the trees of the cultivars: 'Stevnsbaer', 'Słupia Nadbrzeżna' and W10/02. However, these sour cherry trees are among those susceptible to leaf spot, which can be a problem when cultivated in ecological orchards, particularly during seasons with abundant precipitation.

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Table 1. Degree of infection (%) with leaf spot in sour cherry trees recorded three times in 2006 and twice in 2007.

CULTIVAR	2006			2007	
	20 July	21 August	21 September	10 July	1 August
'Stevnsbaer'	40	67.5	75	62	90
W1/02	40	52.5	65	30	58
W2/02	50	50	65	44	74
'Elmer'	80	85	92.5	68	100
'Pamiat Wawiłowa'	30	35	38.5	22	46
W12/02	40	55	67.5	10	46
W9/02	60	70	92.5	68	90
'Włodzimierska'	40	40	75	36	64
W10/02	62.5	72.5	77.5	58	74
'Wanda'	60	65	77.5	46	74
'Naumburger'	60	72.5	77.5	62	88
W7/02	20	30	85	52	88
W8/02	35	40	62.5	48	76
'Słupia Nadbrzeżna'	55	65	85	58	80
'Oblacińska'	35	37.5	50	34	62
'Lucyna'	45	50	52.5	22	40

Table 2. Fruit yield and the incidence of cherry fruit fly and bitter rot in sour cherry fruits in 2006–2007

CULTIVAR	Yield [kg/tree]		Ripening time		% of fruits affected by fruit fly		% of decaying fruits	
	2006	2007	2006	2007	2006	2007	2006	2007
'Stevnsbaer'	0.8	0.8	21/07	10/07	4.5	0	15.0	14.5
W1/02	0.9	1.1	17/07	08/07	12.7	6.3	37.3	20.3
W2/02	1.0	1.1	15/07	08/07	3.0	0.5	27.2	12.1
'Elmer'	0.2	0.2	15/07	08/07	40.5	43.4	46.5	48.6
'Pamiat Wawiłowa '	0.6	0.2	05/07	01/07	3.0	14.5	39.3	30.7
W12/02	0.7	1.9	21/07	10/07	9.3	0	5.1	2.0
W9/02	0.4	0.1	18/07	10/07	5.4	0.7	33.7	12.3
'Włodzimierska'	0.9	0.7	15/07	08/07	15.0	14.9	48.5	40.1
W10/02	0.6	0.1	17/07	09/07	4.0	1.3	25.0	14.0
'Wanda'	2.3	2.7	05/07	02/07	11.5	14.5	28.0	23.0
'Naumburger'	1.8	0.3	10/07	05/07	14.5	29.4	36.0	42.9
W7/02	0.4	0.3	19/07	05/07	21.2	4.2	45.2	35.4
W8/02	0.9	0.9	15/07	07/07	18.5	9.6	40.5	32.1
'Słupia Nadbrzeżna'	1 .9	1.3	20/07	10/07	6.0	0.8	14.5	6.5
'Oblacińska'	2.8	3.1	15/07	05/07	7.5	22.8	35.2	23.4
'Lucyna'	1.8	3.0	10/07	02/07	6.5	31.5	37.0	19.6

EVALUATION OF STRAWBERRY CULTIVARS IN BELARUS

Natallia V. KLAKOTSKAYA

The Republican Unitary Enterprise "INSTITUTE FOR FRUIT GROWING"
2 Kovalev Street, Samokhvalovichy, Minsk region, 223013, Republic of Belarus
e-mail: belhort@it.org.by

Abstract

The aim of our investigations is the evaluation of economical and biological indices of new introduced strawberry cultivars and detection of fruitful, adaptive cultivars for climate of Belarus with high commodity qualities of berries. The experiments are carried out in 2006 – 2007 on a plot of small fruit crops department of the Institute for Fruit Growing. The following cultivars were tested: 'Dukat', 'Feierverk', 'Filon', 'Elkat', 'Rusich', 'Al'fa'; 'Venta' and 'Senga Sengana' as standards. The following parameters were studied: flowering and ripening time, winter hardiness, yield, berry size, chemical composition, appearance and flavor of berries, susceptibility to leaf spot (*Ramularia tulasnei*) and leaf scorch (*Marssonina potentillae*). For two years of the experiment, in the group of medium cultivars, the highest average yield was received from the cultivar 'Rusich'. Cultivars 'Dukat', 'Filon' and 'Rusich' had bigger fruit than the standart 'Venta'. Cultivar 'Feierverk' had fine flavour characteristics. Most resistant to leaf spot and leaf scorch was 'Dukat'. In the late group, the cultivar 'Al'fa' showed the best results. It had the highest yield and higher average fruit weight, better evaluation of appearance and fruit flavour than standard cultivar 'Senga Sengana'.

Key words: Belarus, berry size, cultivar, diseases, phenology, strawberry, winter hardiness, yield

Introduction

Strawberry today is the most popular commercial berry crop in Belarus. The total area of strawberry in Belarus is approximately 8000 ha. The integral part of production of strawberry is used for fresh local markets. Cultivars 'Senga Sengana' (Germany) and 'Venta' (Lithuania) had been the dominant cultivars in Belarus for a long time, but their importance is decreasing now.

'Senga Sengana' is very well adapted to Belarussian climate and has good quality of berries, but the yield is not very high, and it is susceptible to leaf spot and leaf scorch. 'Venta' has good yield and large berries with very good flavour, but berries had low firmness and high susceptibility to *Botrytis cinerea*. Russian cultivar 'Kokinskaya rannyaya' was introduced in Belarus in 1986 and is still dominant between the earliest cultivars. The strawberry cultivar 'Kokinskaya rannyaya' has high winter hardiness and good palatability, but it has low productivity and fine berries (Пантеев, 2002).

The latest cultivars introduced to the Belarussian strawberry industry are 'Dukat' from Poland, 'Vima Zanta', 'Vima Tarda' and 'Vicoda' from Netherlands. Growers are looking for new, better cultivars. Productivity, high quality of berries and resistance to diseases and pests are main properties for acceptance.

Research work with strawberries in Belarus, is concentrated in the Institute for Fruit Growing. One of the main research direction is the testing of newly introduced strawberry cultivars. Our research work is concentrated to determine the suitability of new cultivars for growing in Belarus and compare them with already grown cultivars.

Materials and methods

The experiment was set in May 2005 on a plot of small fruit crops department of Institute for Fruit Growing, Belarus. The evaluation was done on a plot of primary study. With standards: 'Venta' (medium) and 'Senga Sengana' (late) there were compared following cultivars: 'Feierverk', 'Rusich', 'Al'fa' (Russia), 'Filon', 'Dukat', 'Elkat' (Poland). There were 4 replications of 25 plants per plot. Planting distance was 90 x 20 cm.

The experiments are carried out according to "Program and methods of fruit, berry and nut crop breeding" (Orel, 1999).

Evaluated characteristics were as follows: flowering and ripening time, winter hardiness, productivity, berry size, chemical composition, appearance and flavor of berries, susceptibility to leaf spot and leaf scorch. Winter hardiness was evaluated visually in May, using a scale 0-5 (0 = no visual winter injury, and 5 = totally injured/dead plants). The fruit flavour and appearance were evaluated by sensory evaluation, using a scale from 1-5, where 1 = the worst trait evaluation, and 5 = the highest positive evaluation.

The estimation of cultivars on resistance to fungal diseases was carried out under conditions of natural infection, according to methodical instructions of VIR (1972). The disease development estimated in point and calculated under the formula:

$$R = \sum(ab)*100/(NK),$$

where: R – disease development;
$\sum$ (ab) – multiplications sum of the amount of affected plants on the score conforming to them;
N – total of observed plants;
K – the maximum score of a scale.

Cultivars were distributed on groups depending on percent of disease: 0-10 % – relative resistant incidence; 11-25 % – weakly affected; 26-50 % – medium-affected; more than 50 % – highly affected.

The results were statistically evaluated by an analysis of variance. The significance of differences between means was evaluated using Duncan's multiple range test at P = 0/05.

Results

The evaluated cultivars differed at the flowering and ripening time. The data on time of flowering and fruit ripening are presented in Table 1.

The mean results of winter hardiness, productivity and resistance of strawberry cultivars to fungal leaf diseases of two years are given in Table 2.

Means followed by the same letter do not differ significantly according to Duncan's test at P = 0.05.

The climate of Belarus is characterized by humid and cold winters with a stable snow covering, though quite often there are thaws and frosts, which have negative influence on strawberry overwintering. By this reason the winter hardiness is one of the main limiting factors for introducing of new cultivars to Belarus.

For two years of the experiment, in the medium group cultivars, 'Dukat', 'Filon' and 'Rusich' had bigger fruit than the standard 'Venta'. Among late cultivars, average fruit

weight of 'Al'fa' and 'Elkat' was significantly higher that of 'Senga Sengana'.

In the group of medium cultivar, yield of 'Rusich' was significantly higher than the standard 'Venta'. Among late cultivars, yield of 'Al'fa' was significantly higher that of 'Senga Sengana'.

White leaf spot and leaf scorch are one of the most dangerous harmful strawberry leaf diseases in conditions of Belarus.

The cultivar 'Dukat' has exhibited a relative resistance to white leaf spot. Cultivars 'Al'fa', 'Elkat' were affected in weak degree. Four cultivars ('Venta', 'Feierverk', 'Filon', 'Rusich') were referred to group middle-affected cultivars. The cultivar 'Senga Sengana' is affected in the strong degree.

The majority of cultivars are referred in medium affected cultivars group to leaf scorch. The cultivar 'Dukat' is referred to group relative resistant.

Fruit quality was determinate based on more important fruit chemical and organoleptic properties (Table 3). Soluble solids content varied in the studied cultivars from 8.9% ('Dukat') to 11.4% ('Venta'). Total sugars content correlated with soluble solids content, ranging from 5.3 – 7.6%. Total acids content was lowest in the cultivar 'Filon' (0.75%) and highest in the cultivar 'Rusich' (1.29%). Sweetness index (as the sugars-acids contents ratio) was lowest in the cultivar 'Rusich' (4.9) and highest in the cultivar 'Venta' (9.1).

Degustation of berries showed that the berries of cultivars 'Al'fa' and 'Filon' distinguished themselves by the best appearance. Berries of the other cultivars had also good appearance. Only berries of cultivars 'Rusich' and 'Feierverk' were of poorest appearance. Berries of cultivars 'Feierverk' and 'Al'fa' were the most tasteful.

Discussion

Cultivars of the Russian origin 'Al'fa' and 'Rusich' have shown high winter hardiness and productivity in climate of Belarus. The results are in agreement with the results of other researchers (Айтжанова и Андронов, 2003). Cultivars of the Polish origin 'Filon' and 'Dukat' had weak winter injuries, also, in the native country Poland they have shown high winter hardiness (Żurawicz and Masny, 2004). Polish cultivars 'Dukat' and 'Elkat' have shown high productivity in Belarus. These results confirmed the results from previous studies (Żurawicz and Masny, 2002; Masny and Żurawicz, 2004; Uselis, 2005; Шокаева, 2007).

The incidence of disease varied depending on meteorological conditions during 2006 – 2007 years. The peak of incidence white leaf spot for years of researches (2006 – 2007) has fallen to June. In 2006 cold weather with an abundance of deposits and low night temperatures was observed till third decade of July. In such conditions cultivars were affected in a strong degree.

The present field tests showed that the most favorable conditions for incidence of leaf spot are a wet flowering period and a late strawberry season. Our results agree with the results reported of other researchers (Uselis et al., 2006).

The cultivar 'Dukat' was selected on complex resistant to white leaf spot and leaf scorch. Cultivars 'Dukat', 'Elkat' have shown high resistance to leaf spot and leaf scorch in conditions of Lithuanian and Poland (Labanowska et al., 2004; Rugienius

and Sasnauskas, 2005). The German cultivar 'Senga Sengana' in Lithuania also was considerably affected by common leaf spots (Uselis et. al., 2006).

Flavour of berries depends from contents of sugar and an acid (Skupień and Oszmiański, 2004; Зубов, 2004). The Russian origin cultivar 'Feierverk' in Belarus has confirmed the flavour qualities.

Conclusions

Two-year studies of newly introduced foreign strawberry cultivars in the growing conditions of Belarus led to the following conclusions:

In the group of medium cultivars, highest average yield was received from cultivar 'Rusich'. Cultivars 'Dukat', 'Filon' and 'Rusich' had bigger fruit than the standart 'Venta'. Cultivar 'Feierverk' had fine flavour characteristics. Most resistant to leaf spot and leaf scorch was 'Dukat'.

In the late group, the cultivar 'Al'fa' showed the best results. It had the highest yield and higher average fruit weight, better evaluation of appearance and fruit flavour than standard cultivar 'Senga Sengana'.

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Table 1. Some phenological characteristics of strawberry cultivars (2006 – 2007, average)

Cultivar	Beginning of blossom	Full blossom	Beginning of ripening	Maximum of ripening	End of ripening
Medium cultivars					
Venta (st)	16.05	21.05	14.06	21.06	30.06
Dukat	16.05	22.05	13.06	21.06	30.06
Feierverk	21.05	26.05	17.06	23.06	03.07
Filon	21.05	26.05	17.06	23.06	02.07
Rusich	21.05	26.05	18.06	23.06	03.07
Late cultivars					
Senga Sengana (st)	22.05	27.05	19.06	26.06	02.07
Al'fa	24.05	29.05	21.06	28.06	05.07
Elkat	24.05	27.05	24.06	01.07	23.08

Table 2. Winter hardiness, productivity and disease incidence of strawberry cultivars (2006 – 2007, average)

Cultivar	Winter hardiness (scale 0-5)	Average fruit weight. g	Yield. t/ha	Disease incidence. %	
				White leaf spot	Leaf scorch
Medium cultivars					
Venta (st)	1.3	9.5^{ae}	9.7^{bc}	28.4	31.6
Dukat	0.8	10.9^{cd}	9.8^{bcd}	8.1	22.5
Feierverk	1.0	8.6^{a}	9.0^{a}	47.2	38.1
Filon	1.3	10.5^{c}	9.7^{bc}	46.9	43.7
Rusich	0.0	11.3^{cdf}	11.3^{e}	50.0	47.2
Late cultivars					
Senga Sengana (st)	1.0	9.8^{e}	9.5^{ab}	56.3	43.8
Al'fa	0.0	11.6^{f}	11.2^{e}	19.4	25.6
Elkat	0.3	11.4^{f}	10.0^{bd}	19.7	25.6

Table 3. Fruit quality parameters of strawberry cultivars (2006 – 2007, average)

Cultivar	Chemical composition (%)				Organoleptic score	
	Soluble solids	Total sugars	Total acids	Sugars / acids ratio	Appearance (scale 1-5)	Flavour (scale 1-5)
Medium cultivars						
Venta (st)	11.4^{f}	7.3^{def}	0.80^{ab}	9.1	4.3	4.4
Dukat	8.9^{a}	5.3	1.07^{de}	5.0	4.4	4.3
Feierverk	11.0^{f}	7.0^{cde}	0.91^{bc}	7.7	4.1	4.6
Filon	10.0^{de}	6.7^{bc}	0.75^{a}	8.9	4.5	3.9
Rusich	9.4^{abc}	6.3^{ab}	1.29^{f}	4.9	4.1	4.3
Late cultivars						
Senga Sengana (st)	9.7^{cd}	6.0^{a}	0.86^{abc}	7.0	4.4	4.3
Al'fa	10.2^{de}	7.6^{f}	1.18^{ef}	6.4	4.6	4.5
Elkat	9.02^{ab}	6.9^{cd}	0.92^{bcd}	7.5	4.4	4.2

Means followed by the same letter do not differ significantly according to Duncan's test at P = 0.05.

EVALUATION OF EUROPEAN PLUM ROOTSTOCKS IN LATVIA

Jānis LEPSIS, Dzintra DĒĶENA, Viesturs DĒĶENS

Pure Horticultural Research Center,
Abavas 2, Pure, Tukuma raj., LV – 3124, Latvia
e-mail: janis.lepsis@puresdis.lv

Abstract

The performance of eight generative propagated rootstocks (St.Julien INRA 2, St.Julien d`Orleans, St.Julien Noir, Brompton, Wangenheims Zwetsche, St.Julien Wädenswill, Myrobalan, Caucasian plum (local type of myrobalan) and 8 vegetative propagated rootstocks (St.Julien A, Brompton, Ackermann, Pixy, Hamyra, Marianna GF8/1, G5/22, GF 655/2) with the European plum cultivar `Victoria` and hybrid cherry plum cultivar `Kometa Kubanskaya` were evaluated in a field trial in Latvia since 2001. Sufficient winter hardiness is one of the most important criteria for rootstocks in Latvia conditions. Some critical winters were observed during last several years. The winter of 2002/03 had low temperature, until –36°C at a snow level in the orchard. During winters of 2004/05 and 2006/07 low temperatures were observed at the end of the winter, while winter of 2006/07 had high temperature at the beginning. The survival, tree health in general and tree growth parameters were observed to evaluate the tree winter hardiness and renovation ability. The rootstocks had some influence on the tree winter hardiness. All of the European rootstocks had similar or better winter hardiness than the local rootstock Caucasian plum. Unsatisfactory viability was observed for cv. `Kometa Kubanskaya` on the rootstocks St.Julien INRA 2, St.Julien Wädenswill, Myrobalan, Caucasian plum, St.Julien A, Ackermann, Pixy, Hamyra; and for cultivar `Victoria` on the rootstocks Myrobalan, Caucasian plum, Marianna GF 8/1, Pixy and Brompton cuttings.

Key words: cultivars, *Prunus domestica*, *Prunus cerasifera*, winter hardiness

Introduction

European and hybrid cherry plum cultivars are grown in Latvia. However, poor suitability of European rootstocks for Latvian conditions is observed. Caucasian plum (*Prunus cerasifera* Ehrh. var. *divaricata* C.K. Schneid.) is widely used as a plum rootstock in the tree-nurseries. Some investigations are carried out in Latvia State Institute of Fruit-Growing (Kaufmane et al., 2007). Good results in orchard were obtained for hybrid cherry plum cultivars budded on the Caucasian plum, but incompatibility with some European cultivars was observed. Moreover, cultivars grafted on the Caucasian plum have vigorous growth in the orchard.

Quality of trees in the nursery grafted on the rootstocks included in this investigation was evaluated in a previous investigation (1998 – 2000) (Dekens et al., 2004). Good performance showed the generative propagated St. Julien Noir, Wangenheims Zwetsche and St. Julien Wädenswill and the vegetative propagated St. Julien A, Pixy and G5/22.

The aim of the investigation was to find the most suitable plum rootstocks of European origin for Latvian climatic conditions.

Materials and methods

The trial is a part of the international scientific project on the plum rootstocks, where Latvia, Estonia and Belorussia are included. Trial is located at Pure Horticultural

Research Centre. It is situated at 57°02` N and 22°52` E, 50 m above sea level, average temperature per year is +7.5 °C, precipitation sum is 600-700 mm, precipitation in the vegetation period (May – October) is about 300- 350 mm. Irrigation was not available in the orchard, ground-water level is at 1.5-2 m.

The rootstocks included in the investigation can be divided into two groups:

Group 1. Rootstocks of cherry plum (*Prunus cerasifera* Ehrh), 2*n*=16: Myrobalan, Caucasian plum and Hamyra. Marianna GF 8/1, which is an inter-species hybrid, can be included in this group due to its common morphological characteristics. Rootstocks of this group produce vigorous trees, are comparatively drought resistant and suitable for different soil types.

Group 2. Rootstocks of European plum (*Prunus domestica* L), 2*n*=48,: Pixy, St. Julien Wädenswill, Wangenheims Zwetsche, St. Julien A, St. Julien Noir, St. Julien d`Orleans, St. Julien INRA 2, GF 655/2, Brompton, Ackermann and G 5/22. These rootstocks have a delicate, superficial root system. The drought resistance is lower in comparison to cherry plum rootstocks, but these rootstocks are more appropriate for growing in heavy and humid soils. Many of them produce root suckers, which is an inconvenience for orchard management.

The trial was planted in the spring of 2001, one year old trees were planted at 5×3 m spacing (666 trees per ha). Trial was arranged in four replications, three trees per plot. Bare fallow was kept between rows. The vegetative growth and winter hardiness of the European plum cultivar `Victoria` and the hybrid cherry plum cultivar `Kometa Kubanskaya` on these rootstocks were evaluated in the trial. The tree survival, tree health (1 – tree perished, 5 – tree in excellent condition) and tree growth parameters were registered to evaluate the tree winter hardiness. Analyse of variance and Tukey criteria were used for statistical analyse.

In the time period from 2001 there have been several periods with unfavourable meteorological conditions:

The winter of 2002/03 was cold, but stable, minimal registered temperature in January was -28...-31.5 °C. Tree tops got frozen, roots did not suffer, because of sufficient sheet of snow;

In the winter of 2004/05 the most severe frost was registered late – in the 1st decade of March, when minimal temperature was –27.5 °C and 2nd decade with -19.5 °C, flower buds suffered seriously;

Vegetation period of 2006 was notably dry, with precipitation 235 mm. Moisture deficiency on trees was observed in July and beginning of August. Sufficient moisture supply was restored in November. The beginning of the following winter was quite warm, and significant frost was in February – March. Flower buds suffered significantly at the end of the winter.

Results

After winter of 2006/07 unsatisfactory health status had trees of cv. `Kometa Kubanskaya` on rootstocks Ackermann, St. Julien A, Caucasian plum, St. Julien INRA 2, Hamyra, Pixy, Myrobalan, Wangenheims Zwetsche (Figure 1). The best score was for trees on rootstock G 5/22. Differences between these rootstocks are statistically significant.

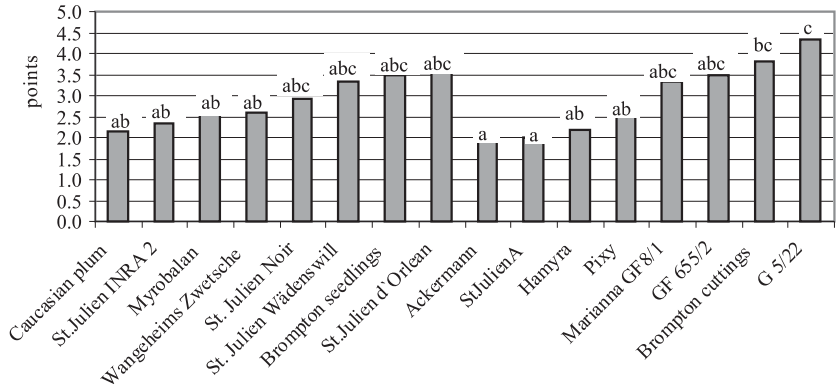

Figure 1. Score of tree overall health status for cv. `Kometa Kubanskaya`

It is notable that cv. `Kometa Kubanskaya` had quite many perished trees. At least one tree on each rootstock was perished. For many trees health status was unsatisfactory (scored by 2), when tree is alive but significantly damaged, can not ensure normal yield and can perish in nearest couple of years. Unsatisfactory vitality (percentage of perished and hardly damaged trees reach 50 %) was observed for trees on St.Julien INRA 2, St.Julien Wädenswill, Myrobalan, Caucasian plum, St.Julien A, Ackermann, Pixy, Hamyra. In its turn acceptable results were obtained on rootstocks Brompton seedlings and cuttings, St.Julien d`Orleans, Marianna GF8/1, G5/22 GF 655/2. Cultivar `Kometa Kubanskaya` is characterised by good renovation ability, therefore it is assumed that part of trees evaluated as hardly damaged will recuperate in some years and will be in satisfactory condition. Nevertheless negative impact on yield will remain. Tree vitality is considered as one of the main criteria for rootstock evaluation.

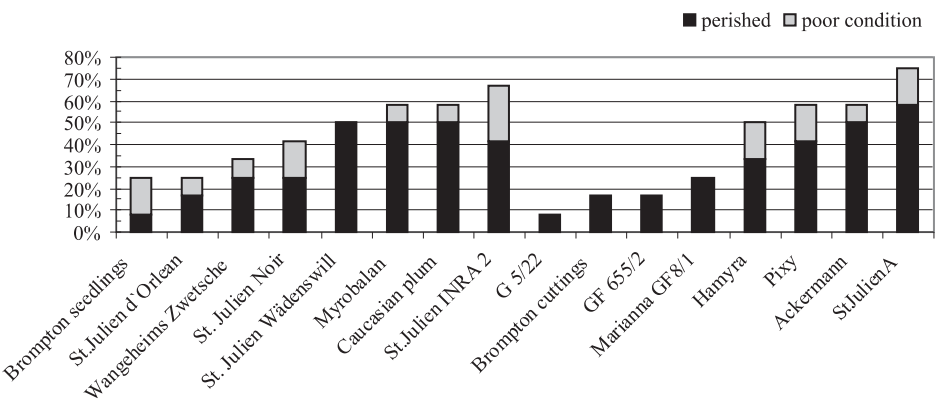

Figure 2. Percentage of perished and heavily damaged trees for cv. `Kometa Kubanskaya`

Growth of suckers is considered as a negative property, because they inconvenience cultivation of orchard and require additional labour for cutting. Growth of suckers was scored from 0 to 3. The less number of suckers was observed for rootstocks Wangenheims Zwetsche, Pixy, Hamyra, St.Julien A (0.2...0.7 points). Most suckers were observed for

Myrobalan (2.1 point). Differences between rootstocks in sucker development were not statistically significant.

In 2007, for cv. `Kometa Kubanskaya` there was observed a tendency that trees show dwarfing effect on Pixy, Ackermann, Wangenheims Zwetsche (2.3 m) and more vigour on Marianna GF 8/1 (2.8 m). Nevertheless, statistically these differences were not significant. Crown projection area in the investigation was between 5 and 8.5 m^2. Less growing space is necessary for trees on St. Julien INRA 2, St. Julien A and Ackermann. Yet the differences between rootstocks in crown projection area were not statistically significant. Crown volume for this cultivar was observed from 13 to 24 m^3. The smallest crown volume had trees on St. Julien INRA 2, St. Julien A and Ackermann. Bigger crowns formed on Caucasian plum, St. Julien Noir and Pixy. The biggest crowns were on Myrobolan and Marianna GF8/1, which belong to the cherry-plum group and have very good compatibility with hybrid cherry plums. Differences in crown volume were not statistically significant.

For cv. `Victoria` less frost damages were observed and overall health status was evaluated higher than for cv. `Kometa Kubanskaya` (Figure 3). Statistically significant differences between rootstocks were not proved, but there was observed a tendency for trees on Myrobalan, Caucasian plum and Pixy to have lower evaluation of tree health.

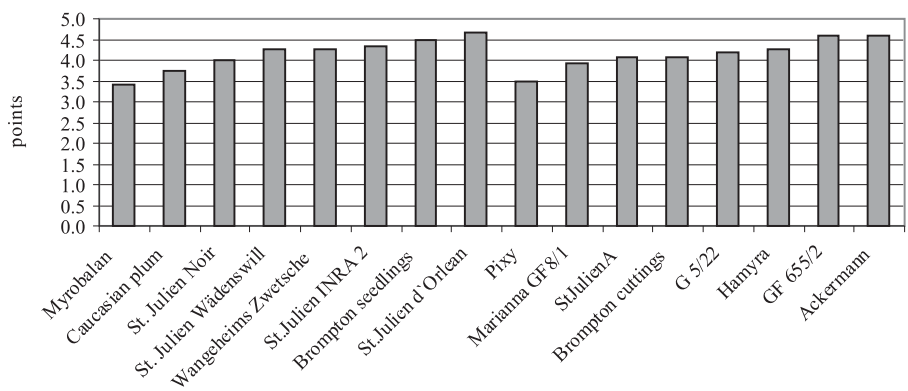

Figure 3. Score of tree overall health status for cv. `Victoria` (significant differences were not stated)

Cultivar `Victoria` had less perished trees (Figure 4) in comparison to `Kometa Kubanskaya`– on Myrobalan (17 %) and St. Julien Noir, GF 8/1, St. Julien A, Hamyra (8%). Unsatisfactory tree health status had 17% of trees on Caucasian plum and Brompton cuttings, 8% trees on Myrobalan, Marianna GF 8/1 and Pixy. The highest amount of perished and hardly damaged trees was on Myrobalan– 25 %, then follow Caucasian plum, Marianna GF 8/1 and Brompton cuttings with 17 %.

Weak sucker formation was observed for cv. `Victoria`. Suckers did not develop almost at all on vegetative propagated rootstocks (0...0.3 points) and Wangeheims Zwetsche (0.2 points). More suckers were developed for trees on Caucasian plum, St.Julien d`Orlean and Myrobalan (1.0...1.2 points). Differences between rootstocks in sucker development are statistically proved, but the observed amount of suckers is not considered as a significant drawback of rootstock.

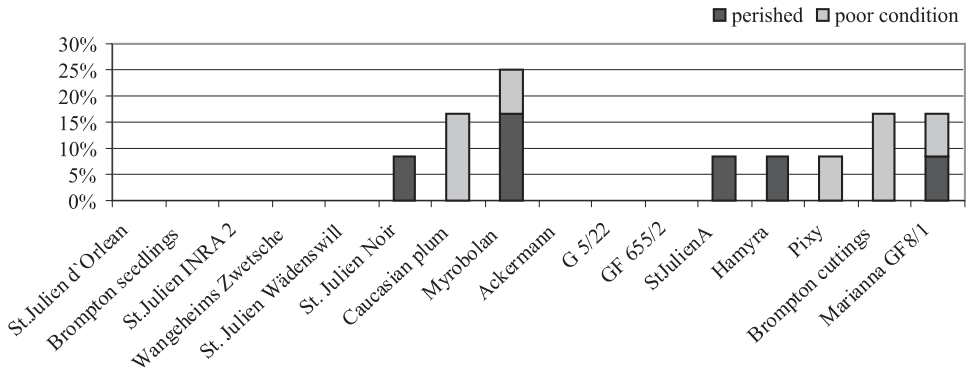

Figure 4. Percentage of perished and hardly damaged trees for cv. `Victoria`

For cv. `Victoria` tree crown and height parameters were also measured. Trees of this cultivar were higher than cv. `Kometa Kubanskaya`, the shortest trees were on Pixy and St. Julien A (2.9 and 3.0 m), significantly higher trees were on rootstocks Brompton (cuttings and seedlings), St.Julien d`Orlean and Hamyra (3.5...3.6 m). Significantly lower trees were on Wangeheims Zwetsche and Ackerman (3.1 and 3.0 m) than on Brompton.

Crown projection area for cv. `Victoria` was from 3.8 m^2 on Pixy to 5.7...5.8 m^2 on Hamyra and GF 655/2. Difference between these rootstocks was statistically significant. For cv. `Victoria` trees with narrower crowns are characteristic in comparison to cv. `Kometa Kubanskaya`.

If to compare tree volume, smallest crown was observed for trees on Pixy (11m^3). Significantly bigger crowns developed trees on St.Julien d`Orlean, St.Julien Noir, Brompton (cuttings and seedlings), GF 655/2, Marianna GF 8/1 and Hamyra (18...20m^3).

Discussion

The investigations proved that cv. `Kometa Kubanskaya` has lower winterhardiness. It was found also in Estonia. In both places similar influence of some rootstocks on the tree winterhardiness was found. Insufficient winterhardiness was found for both cultivars on Pixy and Caucasian plum and for cv. `Kometa Kubanskaya` on Hamyra and St.Julien A. Good winterhardiness for both cultivars was found on Wangeheims Zwetsche, for cv. `Victoria`- on St.Julien Wädenswill. In its turn different observations were registered for cv. `Kometa Kubanskaya` on Brompton seedling and cuttings, for cv. Victoria on Marianna GF8/1 (Jänes and Pae 2004; Jänes et al., 2007).

Tree height was influenced significantly by unfavorable meteorological conditions in the winter of 2006/07, when in the second half of winter shoots were damaged by frost. Therefore after cutting out of dead branches characteristic crown volume for trees was not reached. This caused also significant differences between trees of one rootstock. For example, trees grafted on Caucasian plum had crown projection area between 2 and 7 m^2. Trees grafted on Caucasian plum had untypical small crown, which can be

explained by frost damages. Trees grafted on Marianna GF8/1 were between the biggest ones. This rootstock was noted as vigorous also by others (Hrotko et al., 2002).

Unfavorable climatic conditions influenced vegetative growth of threes of cv. `Victoria` less. It was statistically proved that of generatively propagated rootstocks the lowest height was observed for trees grafted on Wangeheims Zwetsche. Also others have found similar results (Gastol and Poniedzialek, 2007). Among vegetative propagated rootstocks dwarfing effect was found for rootstock Pixy, which is recognized as dwarfing also in other investigations (Wertheim 1998).

There have been different observations on sucker formation. For example it was mentioned by Kosina that GF 655/2 develops more suckers than Pixy, St.Julien A and Myrobalan (Kosina, 2000). However, it was not proved in our investigation.

Conclusions

Trees grafted on Caucasian plum, widely used in Latvia as a seedling rootstock, had one of the lowest evaluation of the health status.

Frost damages of 2006/07 don't allow evaluate correctly rootstock influence on tree habit.

Unsatisfactory vitality for trees of cv. `Kometa Kubanskaya` was found on rootstocks St.Julien INRA 2, St.Julien Wädenswill, Myrobalan Caucasian plum, St.Julien A, Ackermann, Pixy and Hamyra.

Vegetative propagated rootstocks G 5/22, GF 655/2, Marianna GF 8/1, Brompton seedlings and cuttings, St.Julien d`Orlean and Wangeheims Zwetsche can be succesfully used for hybrid cherry plum.

Suitable rootstocks for domestic plums can be Wangeheims Zwetsche, St. Julien Wädenswill, Ackermann and G 5/22, less suitable – Caucasian plum, Myrobalan, Pixy, Brompton cuttings and Marianna GF 8/1.

Unsuitable winter conditions of 2006/07 allowed evaluate tree vitality. For complete evaluation of rootstocks influence on the yield it is necessary to continue investigations.

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PRODUCTIVE PROPERTIES OF SOME MAJOR PLUM CULTIVARS GROWN IN THE REGION OF CENTRAL SERBIA

Milan RAKIĆEVIĆ, Rade MILETIĆ, Marijana PEŠAKOVIĆ

Fruit Research Institute Čačak, Kralja Petra I 9, 32000 Čačak, Serbia;
e-mail: rakicevicm@tfc.kg.ac.yu

Abstract

The paper presents the study of yields (kg/tree and kg/ha) and major fruit properties (fruit size, fruit mass, dry matter content) of plum cultivars sampled from 70 growing plantings set up in the region of Čačak, Central Serbia. Plum cultivars developed at Fruit Research Institute Čačak are primarily grown in this area, i.e. 'Čačanska Rana', 'Čačanska Lepotica', 'Čačanska Najbolja', 'Čačanska Rodna' and 'Stanley'. The paper includes two-year results. Agroecological conditions over the first year (2006) were optimal for plum growing. However, the second year of study (2007) was reported to be the one with excessive droughts, as regards this region, which directly influenced yield and fruit quality. The effect of drought affected plum cultivars differently, hence, the following comparative analysis performed over several years includes different cultivars grown under identical conditions. Depending on tree age, planting distance and growing technology, average yields in cv 'Čačanska Rana' 'Čačanska Lepotica', 'Čačanska Najbolja', 'Čačanska Rodna' and 'Stanley' ranged from 10.0 to 50.0 t/ha, 4.0 to 52.1 t/ha, 17.3 to 83.4 t/ha, 20.5 to 47.2 t/ha and 13.3 to 53.3 t/ha respectively. Superior results were recorded in early cultivars, as these are less rainfall-dependent ('Čačanska Rana' and 'Čačanska Lepotica'). It was steady cropping, ripening time and fruit quality that established these cultivars as highly marketable over the more recent period.

Key words: agroecological conditions, cultivars, fruit, plum, yields

Introduction

The work on breeding and developing new plum cultivars has been permanently pursued at Fruit Research Institute since its foundation in 1946. Fourteen plum cultivars were developed so far, and first five cultivars were released within the first phase -1975 (Ogašanović et al., 2006). Plum cvs 'Čačanska Rana', 'Čačanska Lepotica', 'Čačanska Najbolja' and 'Čačanska Rodna', as most prominent ones, are widely grown in all plum growing regions of Serbia. These cultivars are also commercially grown in a number of European countries, such as Hungary, Czech Republic, Slovakia, Germany, Bulgaria, Romania, etc. as well as in Bosnia and Herzegovina, Croatia, Slovenia, FYR Macedonia and Montenegro (Ogašanović et al., 1993). Besides, the stated cultivars are included in fruit collections of many Fruit Research Institutes abroad where they are used as members in parental combinations in breeding new plum cultivars (Jakob, 2006).

Literature provides a comprehensive description of these plum cultivars, (Mišić, 1986, 1996, 2006; Ogašanović et al., 1993; Milošević, 2002), however their production thereon under particular conditions of growing has been but little investigated in available scientific papers. Yields were studied from the aspects of growing technology and training system (Ogašanović et al., 1996; Janković et al., 1997; Mitrović et al., 2000, 2001; Rakićević et al., 2007; Miletić et al., 2007).

Regardless of the fact that these cultivars have been present in commercial plantings over the past three decades, fruit growers are still interested in these cultivars, showing tendency to extend commercial growing thereof. Bearing in mind the fact that proper cultivar selection is major postulate of successful fruit growing, ensuring steady production of high-quality fruits under specific environmental conditions and maintenance of competitiveness on the market are our major objectives. In addition, global climate change, characterized by temperature rise and drastic rainfall decrease along with mainly traditional methods of growing plum are highly important factors in its production. Regardless of three-decade long existence of these cultivars in commercial plantings, the interest of fruit growers in growing them does not cease. It is for this reason that we began to study productive and major pomological and fruit properties of the stated cultivars in the region of Čačak where they were developed and first experiences in growing commercial cultivars were acquired.

Materials and methods

The research was conducted in the region of Central Serbia (the Čačak region) and it included plum-covered areas of experienced private fruit growers. The results have been obtained from 30 plum orchards. Depending on cultivars, 7 – 22 samples (the total of 69) have been studied. The research included plum cvs 'Čačanska Rana', 'Čačanska Lepotica', 'Čačanska Najbolja', 'Čačanska Rodna' and 'Stanley' which is also grown throughout this region. The two-year results (2006 – 2007) are presented through yield per tree (kg) and area unit (t/ha). The average fruit mass and soluble solids content in cultivars from all orchards have been determined. The results have been statistically processed by determining standard deviation (Dx) and variation coefficient (Cv).

Fruit trees included in these investigations were 3 to 30 years old. Planting distances were different, as presented in Tables for each individual cultivar. All fruit trees were grafted on Myrobalan (*Prunus cerasifera* Ehrh.). Improved pyramidal crown was most applied training system. The soil was mainly grass-covered requiring regular mowing (mulching) over the growing season.

As for nutrition, it was complex mineral fertilizers distributed over winter time that were most commonly used. Nitrogen fertilizers are incorporated at the beginning of the growing period, whereas the organic ones are applied when preparing soil for planting and at planting. Green mass provides improvement of physical and chemical properties of soil. Irrigation of plum orchards is but a rare practice as agroecological conditions are mostly suitable for plum cultivation. In contrast, pruning is compulsory measure, performed mainly over winter, although green pruning has been greatly applied over the most recent period. Intensive control measures against pests and diseases are performed.

Results

The research region belongs to the temperate zone. Mean annual and growing period air temperatures are 10.7°C and 15.9 °C respectively. Mean annual and vegetational precipitation rate amount to 653.7 mm and 426.1 mm respectively, whereas over summer months (June, July, August) these amount to 182.0 mm. The stated data (Table 1)

infer that precipitation rate in 2006 was above average. In 2007, the rainfall over the vegetation period was lower by 34.2 mm and by 85.6 mm during summer.

Being an unsteady bearer, fluctuating from low to high production by years and localities, cv **'Čačanska Rana'** is the least commercially grown as compared to the other studied cultivars. Over the recent years, the demand on the market for this cultivar has been on the rise. High prices have brought about commercial effectiveness of production of cv 'Čačanska Rana', which suggests high quality of this cultivar. In the trial region (Table 2), over 2006, cropping ranged from 8 to 105 kg/tree, whereas in the following year it ranged from 12 to 120 kg/tree (10.0 – 40.0 t/ha and 50.0 – 15.0 t/ha respectively). Average production was 26.1 t/ha (12.5 – 45.0 t/ha). Being an early cultivar, ripening 7 – 8 days after cv 'Ruth Gerstetter' (end of June and early July), its yield is not dependent on drought during summer. In 2007, the yield was higher as compared to the previous year by 8.8 kg/tree (15.0%), i.e. 4.9 t/ha (17.2%). Average fruit mass was 53.7 g (44.6 – 65.5 g), whereas soluble solids content amounted to 12.2% (10.7 – 14.3%).

Plum cv **'Čačanska Lepotica'** is one the most commonly grown cultivars in the region of study. It is an early dessert cultivar of high quality. Being a low vigour cultivar, it can be grown at small spacing in intensive plantings. It is an abundant and steady bearer in all localities. Tolerant of Sharka disease, this cultivar can be grown in Sharka-infected regions. According to our results (Table 3), yields in 2006 and 2007 were 100 – 8 kg/tree (50 – 4 t/ha) and 123 – 10 kg/tree (50 – 5 t/ha) respectively. In the latter year, the yields were higher by 8.6 kg/tree (14.6%), i.e. 5.2 t/ha (15.6%). The average yield over the period of study did not exceed 30.7 t/ha (50 – 4.5 t/ha. Fruit mass ranged from 44.7 – 27.0 g (35.2 g on average), while soluble solids content was 13.6% (16.6 – 10.1%).

'Čačanska Najbolja' is a high quality dessert cultivar characterized by high vigour and productivity. It is recommended to be grown on dwarf rootstocks, in grapevine regions. It is very suitable for freezing, though it can be used for drying and brandy production. It has high cropping potentials which are, among other factors, primarily governed by specificities of the locality, rootstock it is grown on, and weather conditions over the period of flowering. Under the conditions of study (Table 4), in the first season, the yield was average 112.4 kg/tree (50 – 200 kg/tree), i.e. 56.4 t/ha (24.7 – 83.3 t/ha), while in the following season it amounted to 82.5 kg/tree (35 – 160 kg/tree), i.e. 39.8 t/ha (17.3 – 66.7 t/h). The decline in production was reported over the second season by 16.6 t/ha (29.4%), i.e. by 29.9 kg/tree (36.7%).The average yield over the period of study was 48.1 t/ha (21.0 – 75.1 t/ha), fruit mass 35.0 g (27.6 – 43.1 g) and soluble solids content amounted to 15.6% (12.2 – 17.3%).

With regard to the plum covered acreage in this region, cv **'Čačanska Rodna'** is ranked second just after cv 'Čačanska Lepotica' which is most widely grown. Cv 'Čačanska Rodna' is an abundant cropper, suitable for drying, processing and dessert consumption. Its fruits are of superior quality. This cultivar requires severe and regular pruning. When unpruned, it bears alternately, producing thereby small, low-quality fruits. It fares excellent under different growing conditions. Under the conditions of study (Table 5), in 2006 the yield was on average 85.3 kg/tree (26 – 118 kg/tree), i.e. 39.1 t/ha (25.6 – 56.3 t/ha), while in the following season it yielded 70.4 kg/tree (20.5 – 40.8

kg/tree), i.e. 31.6 t/ha (20.5 – 42.5 t/h). The decline in production was reported over the second season by 16.6 t/ha (23.8%), i.e. by 29.9 kg/tree (21.0%). The average yield over the period of study was 35.3 t/ha (24.6 – 47.4 t/ha), fruit mass 37.0 g (42.9 – 29.4 g), whereas soluble solids content amounted to 18.3% (16.8 – 20.5%).

Plum cv **'Stanley'** has been the longest grown plum in Serbia. It has longer tradition of growing in comparison with the cultivars mentioned above. It was developed in the USA and was introduced into the production in 1926. It has been grown in Serbia since 1956, and current tendencies are pretty limited. It is an early cultivar, and bears heavily and regularly. Tolerant of Sharka virus. Fruit is medium large, relatively suitable for different forms of consumption. According to our results (Table 1), in the first season, the yield was averagely 81.0 kg/tree (32 – 120 kg/tree), i.e. 34.6 t/ha (15.0 – 53.3 t/ha), while in the following season it yielded 74.0 kg/tree (40 -115 kg/tree), i.e. 31.7 t/ha (13.3 – 49.4 t/h). The decline in production over the second season was 2.9 t/ha (8.4%), i.e. by 7.0 kg/tree (8.7%). The average yield over the period of study was 32.5 t/ha (14.1 – 51.1 t/ha), fruit mass 27.9 g (21.6 – 32.8 g), whereas soluble solids content amounted to 16.2% (12.3 – 22.0%).

Discussion

Successful fruit production is doubtless primarily governed by the cultivar selection. Besides, appropriate cultural practices and environmental conditions provide full productivity and high yields of a grown cultivar. According to Mišić (1986), yield is complex in character. Highest production is ensured only if a harmonious correlation of all factors is provided, which has been proved in our study. Plum production in Serbia has a long tradition. Plum ranks highest in number of productive trees in comparison with other fruit species. In contrast, plum yields are quite modest, for various reasons. Over 1960 – 1970, the average plum production was about 12.5 kg/tree, being 12.0 kg/tree in the region of Central Serbia. Over 1971 – 1980 and 1980 – 1999, the production was ranging from 10.5 – 11 kg and 10.6 – 11.5 kg/tree respectively (Mišić, 1996).

In the region of study, over 1981 – 1983 and 1997 – 1999, mean production was 13.4 kg/tree and 17.2 kg/tree respectively (Todorović et al., 2000). Based on the Statistics Almanach of the Republic of Serbia (2006) over 2002 – 2006, plum yields were ranging from 4.5 to 13.2 kg/tree in the region of Central Serbia. It was a large number of trees of autochthonous cultivars, the incidence of Sharka virus, inadequate growing technology, droughts, spring frosts, etc. that gave poor production results. In that respect, cultivars which are the subject of our study, can be considered as more productive as compared to those of the old assortment, standing out as major in the current production assortment of Serbia.

A more comprehensive report on yield of the studied cultivars a provided in papers which treat growing technology and training system issues. Thus, investigating how training system affect plum growing (crown shape x planting distance), Janković et al. (1997) found that the initial yield of plum cv 'Čačanska Lepotica' was 7.7 kg/tree (11.4 t/ha), whereas in full cropping values amounted to 41.7 kg/tree (14.7 t/ha). Within the very same investigation plum cv 'Čačanska Najbolja' initially yielded 2.1 kg/tree (0.86 t/ha) and 41.4 kg/tree (17.3 t/ha) in full cropping. Training systems did not

significally affect fruit weight. However, it was not crown shape that exerted noticable effect on productivity of the stated cultivars but planting distance. According to Mitrović et al. (2000), different crown shapes gave the following yields: 'Čačanska Lepotica' (in full cropping) 44.5 -53.5 kg/tree (20.2t/ha to 24.3 t/ha); 'Čačanska Rodna' 53.2 – 65.1 kg/tree (24.1 – 30.6 t/ha); 'Čačanska Najbolja' 44.0 – 55.5 kg/tree (19.9 – 25.2 t/h) and 'Stanley' 42.7 to 61.3 kg/tree (19.4 – 27.8 t/ha). Rakićević et al. (2007) also report on the yield of cvs 'Čačanska Lepotica' and 'Stanley'. Different training systems and spacing over a five-year period resulted in 11.7 to 6.0 kg/tree (15.1 to 27.7 t/ha) (cv 'Čačanska Lepotica') and 4.9 to 8.2 kg/tree(13.7 to 17.7 t/ha). Ogašanović et al. (1996) reported that over a three-year period different rootstocks in trees 15 – 17 years of age gave different yields, i.e. 'Čačanska Rana' yielded 26.0 to 34.7 kg/tree (10.4 – 13.9 t/ha), 'Čačanska Najbolja' 29.2 – 49.7 kg/tree (11.7 – 19.9 t/ha), 'Čačanska Lepotica' 47.7 – 56.7 kg/tree (19.1 – 22.7 t/ha) and 'Stanley' 41.8-35.3 kg/tree (14.1 – 16.7 t/ha). According to Miletić et al. (2007), grown under extreme droughts, 6 – 7 year old trees of cv 'Čačanska Lepotica', 'Čačanska Najbolja', 'Čačanska Rodna' and 'Stanley' yielded 14.6 to 13.4 kg/tree (10.1 to 13.4 t/ha).

Miletić et al. (2007) reported that the plum production over the years with abundant rainfall during summer was higher by 3.6 kg/tree, i.e. 1.8 t/ha (15.5%) as related to those with excessive droughts. Fruit weight and yield were slightly increased in early cultivars ('Čačanska Lepotica' and 'Čačanska Najbolja'), whereas it was lower in late ones ('Čačanska Rodna' and 'Stanley'). Rakićević et al. (2004) reported that, as compared to the control, fertilizer-treated and irrigated cv Stanley resulted in increased yield and fruit weight by 39.8% and 4.9% respectively, and soluble solids content was lower by 3.4%.

Fruit mass of the studies cultivars was within the range reported by Mišić (1986), Ogašanović et al. (1993), Milošević (2002). However, in our trial, fruits of cv 'Čačanska Najbolja' were smaller, which resulted from droughts in 2007, but highly productive nevertheless. Our results suggest that this cultivar yielded highest over the trial period. Besides, fruits of cv 'Čačanska Rodna' are larger than those evidenced by the literature, as in the particular growing region cultivar-specific severe pruning is employed. Besides, yield reduction over the second year in late ripening cultivars has been primarily been exhibited in cv 'Čačanska Najbolja' which is more susceptible to low rainfall, whereas the reduction was less evident in cvs 'Čačanska Rodna' and 'Stanley' respectively. Similarly, cv 'Stanley' is particularly suitable for growing in droughty regions (Stančević, 1997).

The total soluble solids content in fruit flesh has been within the range of cultivar specificities. Early ripening cultivars displayed lower soluble solids content, and later ones higher accordingly. Besides, the total SSC was greatly dependent on the period of harvesting. Thus Miletić et al. (2007) reported that in cv 'Čačanska Lepotica' SSC initially ranged from 8.2 to 8.8%. In mid-season and at the end, the values amounted to 10.0 and 17.5% respectively.

Statistical data processing infer that Standard deviation and variation coefficient were higher for the yield indicators, and lower for fruit mass and total soluble solids (SSC). It was due to old age of fruit trees, training system and applied growing technology. In other words, growing systems (spacing and applied training system), tree age and applied growing technology influenced fluctuation of yields more than it affected fruit mass and overall soluble solids in all studied cultivars.

All the stated results infer that besides cultivar properties, growing technology and agroecological conditions have major influence on productivity and quality of all studied cultivars. According to the results of our investigation, the studied cultivars are recommended to be grown not only in the research region, but abroad as well.

Conclusions

Plum cultivars studied in the region of Central Serbia over 2006 – 2007 resulted in high production.

Average production in cv 'Čačanska Rana' was 26.1 t/ha (12.5 – 45.0 t/ha). In 2007, the yield was higher as compared to the previous year by 4.9 t/ha (17.2%), i.e. 8.8 kg/tree. Average fruit mass was 53.7 g (44.6 – 65.5 g), whereas soluble solids content amounted to 12.2% (10.7 – 14.3-10.7%).

As for cv 'Čačanska Lepotica', the average yield over the period of study did not exceed 30.7 t/ha (4.5 – 50 t/ha. In 2007, the yield was higher by 5.2 t/ha (15.6%), i.e. 8.6 kg/tree (14.6%). Fruit mass ranged from 27.0 – 44.7 g (35.2 g on average), while soluble solids content was 13.6% (10.1 – 16.6%).

The average yield in cv 'Čačanska Najbolja' over the period of study was 48.1 t/ha (21.0 – 75.1 t/ha). The decline in production was reported over the second season by 16.6 t/ha (29.4%), i.e. by 29.9 kg/tree (36.7%). Fruit mass 35.0 g (27.6 – 43.1 g) and soluble solids content amounted to 15.6% (12.2 – 17.3%).

The average yield in cv 'Čačanska Rodna' over the period of study was 35.3 t/ha (24.6 – 47.4 t/ha). The decline in production was reported in all plum orchards over the second season by 16.6 t/ha (23.8%), i.e. by 29.9 kg/tree (21.0%). Fruit mass was 37.0 g (29.4 – 42.9 g), whereas soluble solids content amounted to 18.3% (16.8 – 20.5%).

The average yield in cv 'Stanley' over the period of study was 32.5 t/ha (14.1 – 51.1 t/ha). The decline in production was reported over the second season in all orchards by 7.0 kg/tree (8.7%), i.e. by 2.9 t/ha (8.4%). Fruit mass was 27.9 g (21.6 – 32.8 g), whereas soluble solids content amounted to 16.2% (12.3 – 22.0%).

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Table 1. Precipitation rate over the trial period in the region of Čačak (mm)

Year	Month									
	I-III	IV	V	VI	VII	VIII	IX	X-XII	IV-IX	I-XII
2006	188.0	61.5	30.0	88.3	44.6	176.2	43.0	88.8	443.6	720.4
2007	151.0	13.0	85.3	37.4	28.0	33.7	69.0	253.5	391.9	670.9
Mx	169.5	37.2	57.6	62.8	36.3	104.9	36.0	171.1	417.7	695.6

Table 2. Yield and major properties of plum cv 'Čačanska Rana'

Number of locality	Tree age	Planting distance (m)	Tree/ha	Yield					Fruit mass (g)	Soluble solids (%)
				kg/tree		t/ha		Mx t/ha		
				2006	2007	2006	2007			
1	30	6 x 5	333.3	105	120	35.0	40.0	37.5	50.2	10.7
2	17	4 x 2	1250.0	32	40	40.0	50.0	45.0	50.5	11.3
3	17	6 x 5	333.3	60	70	20.0	23.3	21.6	55.4	12.2
4	8	6 x 5	333.3	70	80	23.3	26.7	25.0	53.6	12.3
5	6	4.5 x 4.5	493.8	45	50	22.2	24.7	23.4	56.3	12.6
6	6	5 x 4	500.0	30	40	15.0	20.0	17.5	65.5	11.8
7	4	4 x 2	1250.0	8	12	10.0	15.0	12.5	44.6	14.3
Mx				50	58.8	23.6	28.5	26.1	53.7	12.2
Dv				29.4	32.3	9.8	11.3	10.5	6.1	1.0
Cv				58.7	54.8	41.5	39.6	40.3	11.2	8.7

Table 3. Yield and major properties of plum cv 'Čačanska Lepotica'

Number of locality	Tree age	Planting distance (m)	Tree/ha	Yield					Fruit mass (g)	Soluble solids (%)
				kg/tree		t/ha		Mx t/ha		
				2006	2007	2006	2007			
1	21	5 x 5	400.0	80	85	32.0	34.0	33.0	35.7	14.5
2	14	4.5 x 4.5	494.0	90	100	44.5	49.4	46.9	36.0	13.7
3	13	5 x 5	400.0	80	95	32.0	38.0	35.0	27.0	13.1
4	13	5 x 4	500.0	85	90	42.5	45.0	43.5	39.3	16.6
5	12	5 x 4	500.0	100	100	50.0	50.0	50.0	29.7	12.3
6	11	5 x 4	500.0	90	100	45.0	50.0	47.5	44.7	13.9
7	10	5 x 5	400.0	55	123	22.0	49.2	35.6	32.0	13.0
8	10	5 x 3	666.6	30	46	20.0	30.7	25.4	35.5	14.6
9	9	6 x 5	333.3	70	70	23.3	23.3	23.3	38.2	12.7
10	8	5 x 4	500.0	100	70	50.0	35.0	42.5	39.2	11.1
11	8	5 x 5	400.0	72	110	28.8	44.0	36.4	35.1	10.1
12	7	4 x 2	1,250.0	24	30	30.0	37.5	33.7	37.2	12.3
13	6	4 x 2.5	1,000.0	22	33	22.0	33.0	27.5	33.8	15.0
14	5	4 x 3	833.3	35	45	29.2	37.5	33.3	32.5	13.2
15	5	4 x 2	1,250.0	19	22	23.8	27.5	25.6	38.4	12.3
16	5	5 x 4	500.0	42	50	21.0	25.0	23.0	33.0	14.0
17	4	5 x 5	400.0	30	20	12.0	8.0	10.0	38.5	15.7
18	4	4 x 1.20	2,083.0	21	25	43.7	52.1	47.9	32.9	14.6
19	4	4 x 3	666.7	32	40	21.3	26.7	24.0	31.5	13.8
20	3	4 x 3	833.3	12	19	10.0	15.8	12.5	38.8	16.6
21	3	5 x 4	500.0	8	10	4.0	5.0	4.5	32.2	13.8
22	3	4 x 1.5	1,666.0	8	10	13.3	16.7	15.0	34.0	12.8
Mx				50.2	58.8	28.2	33.4	30.7	35.2	13.6
Dv				31.4	35.5	12.9	13.4	12.7	3.8	1.6
Cv				62.6	60.4	45.7	40.2	41.2	10.8	11.4

Table 4. Yield and major properties of plum cv 'Čačanska Najbolja'

Number of locality	Tree age	Planting distance (m)	Tree/ha	Yield					Fruit mass (g)	Soluble solids (%)
				kg/tree		t/ha		t/ha		
				2006	2007	2006	2007			
1	33	5 x 5	400.0	200	128	80.0	51.2	65.6	29.2	15.0
2	30	6 x 5	333.3	170	160	56.7	53.3	55.0	33.8	15.0
3	24	4 x 2	1250.0	65	35	81.3	43.7	62.5	34.1	12.2
4	17	5 x 3	666.7	125	100	83.4	66.7	75.1	39.1	15.5
5	14	6 x 5	333.3	147	102	48.9	34.0	41.4	27.6	14.5
6	14	5 x 4	500.0	105	80	52.5	40.0	46.2	43.1	17.1
7	9	5 x 5.5	363.6	70	65	25.5	23.6	24.5	38.5	16.2
8	8	5 x 4	500.0	120	80	60.0	40.0	50.0	35.1	17.3
9	7	4.5 x 4.5	493.8	50	35	24.7	17.3	21.0	33.8	16.6
10	5	4 x 3. 5	714.3	72	40	51.4	28.6	40.0	35.6	16.3
Mx				112.4	82.5	56.4	39.8	48.1	35.0	15.6
Dv				60.0	55.1	20.6	19.1	19.2	4.3	1.4
Cv				42.2	48.9	29.5	36.1	31.2	12.3	6.1

Table 5. Yield and major properties of plum cv 'Čačanska Rodna'

Number of locality	Tree age	Planting distance (m)	Tree/ha	Yield					Fruit mass (g)	Soluble solids (%)
				kg/tree		t/ha		t/ha		
				2006	2007	2006	2007			
1	24	4 x 2	1250.0	26	21	32.5	26.3	29.4	34.5	18.4
2	14	6 x 5	333.3	111	106	37.0	35.3	36.1	39.9	16.8
3	14	6 x 5	333.3	121	116	40.3	38.7	39.5	39.6	20.5
4	14	5 x 3.5	571.4	67	42	38.3	24.0	31.1	42.9	17.6
5	9	4.5 x 4.5	494.0	114	78	56.3	38.5	47.4	35.2	16.8
6	9	5 x 5	400.0	118	102	47.2	40.8	44.0	38.2	19.4
7	9	5 x 5	400.0	87	63	34.8	25.2	30.0	36.6	17.5
8	7	4.5 x 4	555.5	56	37	31.1	20.5	25.8	29.4	19.5
9	5	6 x 5	333.3	77	71	25.6	23.7	24.6	33.5	17.8
10	5	4 x 4	625.0	76	68	47.5	42.5	45.0	40.1	18.4
Mx				85.3	70.4	39.1	31.6	35.3	37.0	18.3
Dv				29.5	29.7	8.6	7.9	7.9	3.7	1.2
Cv				34.6	42.2	22.1	25.1	22.3	10.1	6.3

Table 6. Yield and major properties of plum cv 'Stanley'

Number of locality	Tree age	Planting distance (m)	Tree/ha	Yield					Fruit mass (g)	Soluble solids (%)
				kg/tree		t/ha		t/ha		
				2006	2007	2006	2007			
1	24	4 x 2	1250.0	32	30	40.0	37.5	25.8	32.8	16.7
2	22	5 x 4.5	444.4	120	110	53.3	48.9	51.1	28.6	12.4
3	18	5 x 4.5	444.4	105	93	46.7	41.3	44.0	31.5	12.3
4	14	4.5 x 4.5	494.0	105	100	51.9	49.4	50.6	23.2	20.2
5	13	5 x 4	500.0	96	88	48.0	44.0	46.0	32.5	17.5
6	13	6 x 5	333.3	123	115	41.0	38.3	39.6	29.9	20.1
7	12	5 x 5	400.0	104	96	41.6	38.4	40.0	24.3	17.8
8	12	6 x 5	333.3	120	110	40.0	36.7	38.3	27..1	19.2
9	12	6 x 5	333.3	67	60	22.3	20.0	21.1	32.2	14.1
10	11	5 x 5	400.0	105	95	42.0	38.0	40.0	21.6	22.0
11	9	6 x 5	333.3	70	63	23.3	21.0	22.1	31.4	15.7
12	9	5 x 5	400.0	105	100	42.0	40.0	41.0	29.0	17.6
13	9	5 x 5	400.0	68	65	27.2	26.0	26.6	28.8	15.4
14	7	5 x 5	400.0	70	60	28.0	24.0	26.0	25.9	15.7
15	7	5 x 5	400.0	53	46	21.2	18.4	19.8	30.2	13.3
16	7	5 x 5	400.0	52	48	20.8	19.2	20.0	27.1	12.8
17	7	6 x 5	333.3	45	40	15.0	13.3	14.1	25.7	14.2
18	7	6 x 3	555.5	50	43	27.8	23.9	25.8	25.8	15.3
19	5	5 x 3.8	526.3	70	64	36.8	33.7	35.2	25.3	15.5
20	4	5 x 5	400.0	60	55	24.0	22.0	23.0	26.1	16.1
Mx				81.0	74.0	34.6	31.7	32.5	27.9	16.2
Dv				27.7	26.2	11.2	10.7	11.0	3.2	2.6
Cv				34.1	35.3	32.5	33.7	33.9	11.3	16.4

PRODUCTIVITY OF APPLE CV 'IDARED' GROWN IN THE REGION OF ČAČAK (SERBIA)

Milan RAKIĆEVIĆ, Rade MILETIĆ, Marijana PEŠAKOVIĆ

Fruit Research Institute Čačak, Kralja Petra I 9, 32000 Čačak, Serbia
e-mail: rakicevicm@tfc.kg.ac.yu

Abstract

Fruit production is primarily governed by proper cultivar selection. Besides, it is appropriate growing conditions that ensure stable production of high-quality fruits and continuity on the market. Some productive and pomological-technological properties of apple cv 'Idared' grown in the region of Čačak (Central Serbia) have been studied. The paper presents two-year results (2006 and 2007) of the study of productivity under the conditions of irrigation, fertigation and without irrigation. The study was performed in commercial plantings of the most prominent fruit growers of this region.

Yields ranged from 23.5 t/ha (younger trees) to 110.9 t/ha (trees in full cropping), depending on tree age, planting density, rootstock and applied cultural practices in the commercial plantings. During the first year of study, from early June to late August, 309 mm of rainfall was recorded, and only 99 mm over the second year of study was reported. Therefore, low rainfall and long periods of drought over the growing season without irrigation of plantings resulted in lower yields by some 20 – 40% , as compared to the first year of study.

Irrigation and fertigation applied during the first year of study ensured higher yields. The results obtained over the second year of study suggest exceptionally favourable effect of these practices when applied under extremely unfavourable conditions. Growing conditions and applied cultural practices clearly influenced fruit size, soluble solids content and fruit ripeness.

Key words: apple, cultivar, cultural practices, fruit quality, yields

Introduction

'Idared' is the predominant cultivar in the apple assortment of Serbia. It is an American cultivar derived from the cross of 'Jonatan' x 'Wagener' in 1942. It is grown worldwide. It was introduced in Serbia in 1961 (Mišić, 1989). Gvozdenović and Dulić (1982), Mišić et al. (1993) etc. have described pomological and technological properties of this apple cultivar grown under various agroecological conditions. This cultivar is reported to be abundant and regular cropper. Depending on different agroecological conditions, rootstock, training system and cultural practices, the production and fruit properties thereof differed greatly (Rahović, 1985; Šalipurović et al., 2001; Nidžović et al., 2000; Veličković et al., 2006, etc.). Irrigation, particularly fertigation, are more steadily being applied in modern intensive production. The effect of the stated measures are reflected in the increase in yield and fruit mass (Rakićević et al., 2005, 2006, 2007; Miletić et al., 2002).

It is appropriate growing conditions that ensure stable production of high-quality fruits and continuity on the market. Therefore, some productive and pomological-technological properties of apple cv 'Idared' grown in the region of Čačak (Central Serbia) have been studied.

The aim of the research was to investigate productive and pomological-technological properties of apple cv 'Idared' grown in the region of Čačak (Central Serbia) from the aspect of agroecological conditions and applied growing system and cultural practices.

Materials and Methods

Aiming to study commercial productivity, the two-year results (2006 – 2007) performed in cv 'Idared'-grown commercial plantings of fruit growers of Čačak have been presented. The production of plantings where irrigation was being applied over summer have particularly been stated. Apart from that, some results of the application of fertirrigation (fertiliser-added irrigation) in this cultivar have also been presented.

The data referring to the age of the trees, rootstock, spacing and number of trees per hectare in each planting have been shown in the tables. Yield has been determined in kg per tree and t/ha. Fruit weight (mass by technical balance), soluble solids content (SSC by refractometer) and ripeness (iodine method) have been determined in laboratory. The results have been processed statistically by standard deviation (Dx) and variation coefficient (Cv).

Results

The research region is in temperate zone. Mean annual air temperature is 10.7°C, whereas mean temperature over growing season does not exceed 15.9°C. Mean annual rainfall rate is 653.7 mm, whereas mean rainfall rate over growing season and over summer is 426.1 mm and 182.0 mm respectively.

Over the first year of study, annual precipitation (720.4 mm) and those over the growing season (443.6 mm) were exceptional, higher than the average for the specific region, and were uniformly distributed. In the following year, reported annual precipitation rate was only 670.9 mm, while over the vegetation period the rate did not exceed 391.9 mm. Over summer of the respective year, in June, July and August, rainfall rate was poor. Excessive droughts were reported to prevail over this research period, which greatly affected productivity and quality of apple fruits.

The research terrains lie in hilly and hilly-mountainous region characterized by different soil types. Soil fertility differs by fruit species and applied growing technology. The soil of the plantings is approximately neutral containing 8.37 – 12.48% $CaCO_3$, low humus content (0.74 – 1.71%), low nitrogen content (0.04 – 0,09%), low to medium P_2O_5 content (1.0 – 5.9 mg/100 g) and well provided with K_2O (12.6-21.3 mg/100 g).

The apple planting with applied fertigation the soil is approximately neutral containing 8.37 – 12.48% $CaCO_3$, low humus content (0.74 – 1.71%), low nitrogen content (0.04 – 0.09%), low to medium P_2O_5 content (1.0 – 5.9 mg/100 g) and well provided with K_2O (12.6-21.3 mg/100 g).

However, alluvial soils are predominant in lower terrains lying in the valley of the Zapadna Morava river. This soil is characterized by fine grain-metric composition, neutral reaction (pH value 6.87 – 6.95), $CaCO_3$ content ranging from 7.81 – 7.95% and low humus content (1.00 – 3.04%). Nitrogen content is low to medium (0.05 – 0.15%), whereas the content of P_2O_5 and K_2O is medium to high, i.e. 9.10 – 30.0 mg/100 g and 12.60 – 26.10 mg/100 g respectively.

The average production of apple cv 'Idared' grown without irrigation in the first year of study – 2006 (Table 1), governed by different conditions (tree age, rootstock, spacing and growing technology) was as follows: 76.0 kg/tree (196.0-23.4 kg/tree), i.e. 54.8 t/ ha (112.7-23.8 t/ha). In the following year, rainfall deficiency and high temperatures during summer caused decline of production resulting in average 68.0 kg/tree (190.0-19.8 kg/ tree), i.e. 46.3 t/ha (109.2-23.3 t/ha). Over the second year of study, the yield was lower by some 8.0 kg/tree on average (11.8%), i.e. by 8.5 t/ha (18.3%). The average yield in all studied plantings amounted to 52.3 t/ha (110.9-23.5 t/ha).

When irrigation was applied (Table 2) in several plantings, average yield in the first year of study amounted to 82.3 kg/tree (175.0-53.3 kg/tree), i.e. 92.0 t/ha (116.7-66.2 t/ha). Regardless of the irrigation measures applied in the following year, the average production was less – 76.7 kg/tree (160.0-50.0 kg/tree), i.e. 85.9 t/ha (106.7-60.5 t/ ha). Decline in the production was slight, 5.6 kg/tree on average (7.3%), i.e. 7.17 t/ha (7.1%). The average production of the irrigation-assisted plantings was 88.9 t/ha (111.7-63.3 t/h).

The results presented in Tables 1 and 2 cannot be directly compared. However, it is obvious that yields were higher when irrigation was applied. In the first year, the rise was reflected in 6.3 kg/tree (8.3%), i.e. 27.5 t/ha (50.0%). In the following year, irrigation-assisted plantings gave higher yields by 8.7 kg/tree on average (12.8%), i.e. 39.6 t/ha (85.5%). As for the period of study, the difference was 36.6 t/ha (70.0%) on average.

When irrigation was not applied (Table 3), average fruit mass was 164.9 g (212.3-116.2 g), soluble solids content 13.4% (15.1-10.4%) and ripeness 5.4 (6.2-4.1). In contrast, when irrigation was applied (Table 4), average fruit weight, soluble solids content and ripeness were 197.8 g (226.0-168.8 g), 12.7% (14.9-9.8%) and 4.6 (7.0-3.3) respectively.

Similar to yield values, these data cannot be directly compared. However, the fact remains that fruits were larger by 32.9 g (19.9%) when trees were irrigated. In contrast, soluble solids content and ripeness values were lower by the absolute 0.7% (5.5%) and 0.8% (17.4%) respectively.

As regards the statistics, standard deviation and variation coefficient were higher in respect of yield indicators, and lower in fruit mass, SSC and ripeness. It was due to old age of trees, rootstocks on which these were grafted, training system and applied cultural practices.

As for the fertigation trial (Table 5), the first variant included the application of Kemira Ferticare III (NPK 10:5:25 + MgO (2.5%) + S (1.7%) + Fe (0.01%), and Compo-Nitrofoska (NPK 15:5:30 + Mgo + S + microelements) in the second. The control was the third variant (irrigation without fertiliser). Three-year average results (2005-2007) suggest that grown under fertigation conditions the plantings were more productive as compared to the control. The yields were higher by 4.79 and 4.54 kg/tree, i.e. 30.1 and 28.5%. From the aspect of yield per unit of arable land, the yields were higher by 3.35 and 2.82 t/ha, i.e. 7.1 and 8.4%. Similarly, fruits were larger by 11.8 g (6.7%) and 7.1 g (4.0%). In contrast, soluble solids content was higher by 2.12% and 1.50%, i.e. 18.4% and 12.3% as related to the control, as well as the ripeness, i.e. 2.46 (46.7%) and 2.54 (49.7%).

Discussion

The apple production in Serbia was different over different periods. Thus, over 1960 to 1970, the average yield per tree ranged from 16.7-19.4 kg, 18.8-21.1 kg over 1971 to 1980, 16.7-18.8 kg over 1981 to 1990 and 11.0-18 kg over 1991 to 2000 (Mišić, 1987; Marković et al., 1997; Milutinović et al., 2001). According to Marković et al. (1997), 65% of the total apple yield is produced in Central Serbia. According to Statistical Almanach of RS (2006), over 2002 to 2006 the apple production in Serbia ranged from 6.6 to 16.8 kg/tree, while it was 7.4-16.4 kg/tree in Central Serbia. It was due to a considerable number of extensive plantings, old apple assortment, old technology of growing and unfavourable agroecological conditions. On the other hand, modern intensive plantings where 50 t/ha are produced can be found in Serbia (Jovanović et al.,1997), which has been suggested by our results.

Our work infers that the production of apple cv 'Idared' is higher on trees grown on vigorous rootstocks (MM 106) even though these were older than trees grown on dwarf rootstocks (M 26 and M 9). Thus, Šalipurović et al. (2005) report on the highest initial cropping of apple cv 'Idared' grown on rootstock M 26 (6.47 kg/tree, i.e. 10.2 t/h), whereas the production was lower in trees grown on M 9 rootstock (4.7 kg/tree, i.e. 7.93 t/ha) and the lowest in those grown on MM 106 (2.59 kg/tree, i.e. 3.3 t/h). According to Šalipurović and Džamić (2001), SSCs grown on rootstocks M 9, M 26 and 106 were 13.62%, 12.67% and 12.72% respectively. Similarly, Rahović (1985) reports that the production of cv 'Idared' trees grafted on M9 and planted at spacing 4 x 1.5 m gave 2.0 to 35.0 kg/trees (18.6 kg/tree, i.e. 3.8 – 66.7 t/ha on average) over eight years. According to Nidžović et al. (2000), different rootstocks and localities affect chemical composition of apple cv 'Idared'. In a locality in the region of Čačak, SSCs of fruits grown on vegetative rootstocks M 9, M 26 and MM 106 were 16.1%, 16.3% and 15.9% respectively, whereas grown in the region of Varvarin these values were 15.8%, 15.6% 15.3%.

Intensity of summer pruning and crown form also influenced tree production. According to Veličković et al. (2006), the production of cv 'Idared' ranged from 19.4 to 27.6 t/h (spindle) and from 24.3 to 27.9 t/ha (palmette). Fruit mass ranged from 164 to 172 g and 149 to 159 g, and SSC from 14.7 to 15.1% and 14.8 to 15.4% in respective crown forms.

Tree production was governed by agroecological conditions over the entire study period. In the first year, rainfall amounted to 309 mm, while it was only 99 mm in the second year of study. These modest rainfall rates and long-term droughts over the growing period (without irrigation) brought about decline in tree production by 40.6 % in the second year. These results suggest that irrigation, notably fertirrigation, is considered a compulsory measure in modern apple production. Thus, Rakićević et al. (2006) within the trial which included irrigation of cv 'Idared' trees (region of Čačak), found the increase in yield and fruit weight by 26.3% and 18.3%, whereas SSC was lower by 0.2%. The effect of irrigation was more pronounced in years with higher rainfall rate than in droughty ones (Miletić et al., 2002), which has been confirmed in our work. Fertirrigation measures are widely applied in large-scale apple production. The results reported by Rakićević et al. (2007, 2008) comply with the ones stated in Table 5.

The stated results infer that apple cv 'Idared' is a potentially high cropper. Grown

under favourable conditions and when adequate growing technology is applied it fares outstandingly. This provides its competitiveness on the market, regardless of the fact that some promising apple cultivars are constantly being introduced into production (Gvozdenović et al., 2007).

Conclusions

The average yield in all studied plantings amounted to 52.3 t/ha (110.9-23.5 t/ha). When irrigation was applied, the production was 88.9 t/ha (102.2-63.3 t/ha).

When irrigation was applied, the production varied among years. The average difference for the period of study was 36.6 t/ha (70.0%).

When irrigation was not applied, the average fruit mass, SSC and ripeness amounted to 164.9 g (212.3-116.2 g), 13.4% (15.1-10.4%) and 5.4 (6.2-4.1) respectively. In contrast, when irrigation was applied, these values were 197.8 g (226.0-168.8 g), 12.7% (14.9-9.8%) and 4.6 (7.0-3.3) respectively.

Three-year average results (2005-2007) suggest that grown under fertirrigation conditions the plantings were more productive as compared to the control. The yields were higher by 30.1 and 28.5%. From the aspect of yield per unit of arable land, the yields were higher by 7.1 and 8.4%. Similarly, fruits were larger by 6.7% and 4.0%. In contrast, soluble solids content was higher by 18.4% and 12.3% as related to the control, as well as the ripeness, i.e. 2.46 (46.7%) and 2.54 (49.7%).

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Table 1. The production of apple cv 'Idared' in the region of Čačak grown without irrigation

Num. of planting	Age	Rootstock	Spacing	Trees/ ha	Yield				Mx t/ha
					kg/tree		t/ha		
					2006	2007	2006	2007	
1	25	MM 106	4.7 x 3.7	575.0	196.0	190.0	112.7	109.2	110.9
2	20	MM 106	5 x 1.70	1.176.5	25.8	19.8	30.3	23.3	26.8
3	15	MM 106	5 x 4	500.0	135.0	120.0	67.5	60.0	63.7
4	14	MM 106	5 x 3.5	571.4	104.0	95.0	59.4	54.3	56.8
5	14	MM 106	4.7 x 3.7	575.0	132.3	120.4	76.1	69.2	72.6
6	14	MM 106	4 x 3	833.3	67.5	55.0	56.3	45.8	51.0
7	14	MM 106	4 x 4	625.0	80.0	72.0	50.0	45.0	47.5
8	11	MM 106	5 x 3.5	571.4	124.5	103.0	71.2	58.8	65.0
9	10	MM 106	5 x 3	666.7	78.0	73.0	52.0	48.7	50.3
10	8	MM 106	5 x 3.5	571.4	90.0	80.0	51.4	45.7	48.5
11	6	MM 106	4 x 3	833.3	56.0	48.0	46.6	40.0	43.3
12	15	M 26	4 x 2	1.250.0	35.0	33.0	43.7	41.2	42.4
13	14	M 26	4 x 2	1.250.0	23.4	22.0	29.2	27.5	28.3
14	12	M 26	4 x 1.5	1.666.7	52.0	44.0	86.7	73.3	80.0
15	11	M 26	4.5 x 2	1.111.0	40.0	30.0	44.4	33.3	39.0
16	6	M 26	4 x 3	833.3	28.5	28.0	23.8	23.3	23.5
17	8	M 9	4 x 1.5	1.666.7	23.9	23.5	39.8	39.2	39.5
Mx					76.0	68.0	54.8	46.3	52.3
Dx					47.7	44.9	22.2	20.5	21.0
Cv					62.8	66.0	40.6	44.2	40.3

Table 2. The production of irrigated apple cv 'Idared' grown in the region of Čačak

Num. of planting	Age	Rootstock	Spacing	Trees/ ha	Yield				Mx t/ha
					kg/tree		t/ha		
					2006	2007	2006	2007	
1	24	MM 106	4 x 2.5	1000.0	84.0	82.0	84.0	82.0	83.0
2	18	MM 106	5 x 3	666.7	175.0	160.0	116.7	106.7	111.7
3	10	MM 106	5 x 1.75	1142.0	58.0	53.0	66.2	60.5	63.3
4	10	MM 106	4 x 2	1250.0	64.3	58.0	80.4	72.5	76.4
5	15	M 26	4 x 1.5	1666.7	59.4	57.0	99.0	95.0	97.0
6	12	M 26	4 x 1.3	1980.1	53.3	50.0	105.5	99.0	102.2
Mx					82.3	76.7	92.0	85.9	88.9
Dx					42.6	38.6	16.9	15.9	16.4
Cv					51.7	50.5	18.3	18.6	18.4

Table 3. Fruit properties of apple cv 'Idared' grown without irrigation

Num. of planting	Tree age	Rootstock	Spacing	Fruit mass (g)	Soluble solids content (%)	Ripeness
1	25	MM 106	4.7 x 3.7	116.2	14.6	4.5
2	20	MM 106	5 x 1.7	141.1	13.9	5.7
3	15	MM 106	5 x 4	126.5	14.4	5.5
4	14	MM 106	4 x 1.5	186.2	12.3	6.0
5	14	MM 106	4.7 x 3.7	160.3	12.0	5.1
6	14	MM 106	4 x 3	212.3	11.9	5.8
7	14	MM 106	4 x 4	176.2	13.5	6.4
8	11	MM 106	5 x 3.5	193.0	13.8	6.2
9	10	MM 106	4 x 4	201.0	12.1	6.1
10	8	MM 106	5 x 3.5	194.2	12.8	5.3
11	6	MM 106	4 x 3	160.6	13.6	5.1
12	15	M 26	4 x 2	144.3	14.2	5.8
13	14	M 26	4 x 2	148.8	14.2	4.1
14	12	M 26	4 x 1.5	138.2	15.1	4.7
15	11	M 26	4.5 x 2	146.6	14.8	5.1
16	6	M 26	4 x 3	165.1	13.7	5.1
17	8	M 9	4 x 1.5	192.7	10.4	5.7
Mx				164.9	13.4	5.4
Dx				27.4	1.3	0.6
Cv				16.6	9.2	11.3

Table 4. Fruit properties of irrigation-assisted apple cv 'Idared'

Num. of planting	Tree age	Rootstock	Spacing	Fruit mass (g)	Soluble solids content (%)	Ripeness
1	25	MM 106	4 x 2.5	181.6	9.8	3.3
2	18	MM 106	5 x 3	216.5	14.9	7.0
3	10	MM 106	5 x 1.75	207.8	13.2	5.3
4	10	MM 106	4 x 2	186.4	11.9	3.3
5	15	M 26	4 x 1.5	168.8	12.8	4.8
6	12	M 26	4 x 1.3	226.0	13.4	3.8
Mx				197.8	12.7	4.6
Dx				20.3	1.6	1.3
Cv				10.3	12.4	28.6

Table 5. The influence of fertirrigation on the commercial productivity of apple cv 'Idared'

Fertiliser/ variant	Yield		Fruit weight (g)	SSC (%)	Ripeness
	kg/tree	t/ha			
Kemira Ferticare	20.44	42.58	187.0	12.15	5.27
Compo Nitrofoska	20.69	43.11	182.3	11.53	5.19
Control without irrigation	15.90	39.76	175.2	13.65	7.73

PRODUCTIVITY AND FRUIT QUALITY OF LITHUANIAN APPLE SELECTIONS

Audrius SASNAUSKAS[1], Dalia GELVONAUSKIENĖ[1], Bronislovas GELVONAUSKIS[2], Pranas VIŠKELIS[1], Česlovas BOBINAS[1]

[1]Lithuanian Institute of Horticulture, Kauno 30, LT-54333,
Babtai, Kaunas district, Lithuania.
e-mail: A.Sasnauskas@lsdi.lt
[2]Plant Gene Bank, Stoties str. 2, LT-58343 Akademija, Kėdainiai district, Lithuania

Abstract

Advanced selections No 19943 ('Kaunis' x 'Prima'), No 20409 ('Auksis' x 'Katja'), No 20244 ('Noris' x 'Prima'), No 21199 ('Katja' x 'Prima'), No 21664 ('Prima' x 'Idared'), No 22159 ('Noris' x 'Idared') with standard cultivars 'Tellissaare' (Estonia), 'Štaris' and 'Auksis' (Lithuania) were tested at the Lithuanian Institute of Horticulture in 2001–2006. Two-year-old apple trees on rootstock M.26 were planted in an orchard in 2001. Trees were placed at 4 × 2 m and 3 trees presented selection, 1 tree per replication. Apple tree yield, fruit size, picking time, storage life, fruit quality, chemical content and colour coordinates were investigated.

It was determined that cumulative yield of selections No 20244 and No 21199 was the highest. The longest period of storage had selection No 21199, standard cultivars 'Tellissaare' and 'Štaris'. Fruit taste and quality of selections No 20244, No 22159 and cultivar 'Auksis' were the best. Selections No 20244, No 21664, No 22159 and cultivar 'Auksis' had uniform fruit size. Cultivars 'Štaris', 'Auksis', selections No 20244 and No 22159 had the largest fruits. Biochemical characteristics of fruit distinguished selections No 21199 and No 21664. Fruit skin firmness of selections No 22159 and cultivar 'Tellissaare' was the highest, flesh firmness – of selection No 19943 and cultivar 'Tellissaare'. The highest amount of juice had selection No 19943. The highest parameter of red colour had No 21199. The advanced selections No 20244 and No 21199 can be selected as the best ones among the tested selections.

Key words: chemical content, fruit quality, productivity

Introduction

Apple breeding work in Lithuania started at the Lithuanian Institute of Horticulture in 1952 and is continued by now. The aim of the Lithuanian apple breeding programme is to combine improved resistance to scab (*Venturia inaequalis*), fruit quality and yield in new cultivars. Large scale apple selection trials are constantly carried out at the Lithuanian Institute of Horticulture (Sasnauskas et al., 2006a; Sasnauskas et al., 2006b; Gelvonauskienė et al., 2006; Sasnauskas et al., 2007). Several commercially grown cultivars: 'Auksis', 'Noris', 'Štaris' and 'Aldas' were developed. 'Skaistis' and 'Rudenis' – scab immune apple cultivars – were selected according to the apple breeding programme in 2005 (Sasnauskas et al., 2005; Sasnauskas et al., 2006a).

Fruit yield and quality have become more important for consumers and producers (Stainer et al., 1996; Zanela, 2006). More investigation is needed about this value of new apple selections. The objective of this study was to evaluate yield and fruit quality in six apple selections.

Materials and methods

Trial years and place. The trial which involved 9 apple cultivars and selections was planted at the Lithuanian Institute of Horticulture in the spring of 2001. Trees were grafted on M.26 rootstock. Evaluation and characterization of the cultivars and selections were performed in 2002-2006.

Meteorological conditions. In 2002-2003 the temperature in December (5°C) and February (1.7°C) was lower, while in 2003-2004 the temperature in December (1.9°C) and February (2.5°C) was higher than multiannual value. In 2004 the late spring frost at the beginning of bloom injured blossoms. At this time the minimal air temperature above the ground dropped from -0.3°C to -4.9°C, which decreased fruit set.

Plant material. The following advanced selections were compared with the standard cv. 'Tellissaare' (Estonia), 'Štaris' and 'Auksis' (Lithuania): No 19943 ('Kaunis' x 'Prima'), No 20409 ('Auksis' x 'Katja'), No 20244 ('Noris' x 'Prima'), No 21199 ('Katja' x 'Prima'), No 21664 ('Prima' x 'Idared') and No 22159 ('Noris' x 'Idared').

Experimental design. The trees were planted at the distance of 4x2 m. The trial was established in three replications. Each plot contained 1 fruit-tree. They were formed as spindle. Growing, fertilizing, pest, disease and weed control, soil cultivation, pruning, shaping and care of apple cultivars and promising hybrids were maintained as recommended for commercial orchards.

Observations and statistical analysis. The observations on fruits and trees have been done according to the standards used by the EUFRIN working group on apple and pear cultivar evaluation. In the trial the following characters of apple hybrids and cultivars was established: yield, t ha^{-1}; distribution of fruits to classes according to diameter, %; dates of harvesting time and storage life; fruit weight, g; quality evaluation of fruits, scores; biochemical composition, %; output of apple juice, %. Firmness of apple skin was evaluated by a penetrometer IDP-500 (Russia), equipped with a 1 mm^2 tang to determine the force of pressure on fruit at a speed of 0.75 mm/s, on flesh – by a penetrometer FT 327 (Bishop, Italy) with the tang diameter of 11.3 mm. For each selection or cultivar 10 fruits were analyzed. Colour coordinates (L*, a*, b*) measurements were made with a portable spectrophotometer MiniScan XE Plus (Hunter Associates Laboratory, Inc., Reston, Virginia, USA). The colorimeter was set to measure total reflectance with illuminant D65 and a 10° observation angle. The parameters L*, a* and b* (lightness, red value and yellow value, respectively, on the CIELab scale) were measured, converted into hue angle ($H° = \arctan(b^*/a^*)$ and chroma ($C = (a^{*2}+b^{*2})^{1/2}$) (McGuiere, 1992)

All data were subjected to analysis of variance. The significance of differences between the cultivars and advanced selections was estimated at 0.05 level (Fisher's Protected LSD).

Results

Significant differences among cultivars and selections in yielding capacity were recorded starting from the first year of cropping. Cv. 'Tellissaare' (15.6 t ha^{-1}) and selection No 20409 (7.9 t ha^{-1}) produced a higher yield in the second year in orchard (Figure 1). In the third year in orchard apple trees of selections No 20244 (60.4 t ha^{-1}) and No 21199 (30.8 t ha^{-1}) with cv. 'Auksis' (45 t ha^{-1}) produced a higher yield, while

trees of selections No 19943 (0.2 t ha^{-1}) and No 21664 (0.3 t ha^{-1}) bore less fruits. In the fourth year in orchard apple trees of selections No 21664 (23.2 t ha^{-1}) and No 21199 (17.8 t ha^{-1}) with cv. 'Auksis' (19.9 t ha^{-1}) produced as higher yield, while No 20409 (0.3 t ha^{-1}) produced lower. Selections No 20244 and No 21199 were on the top positions during fifth and sixth year in orchard.

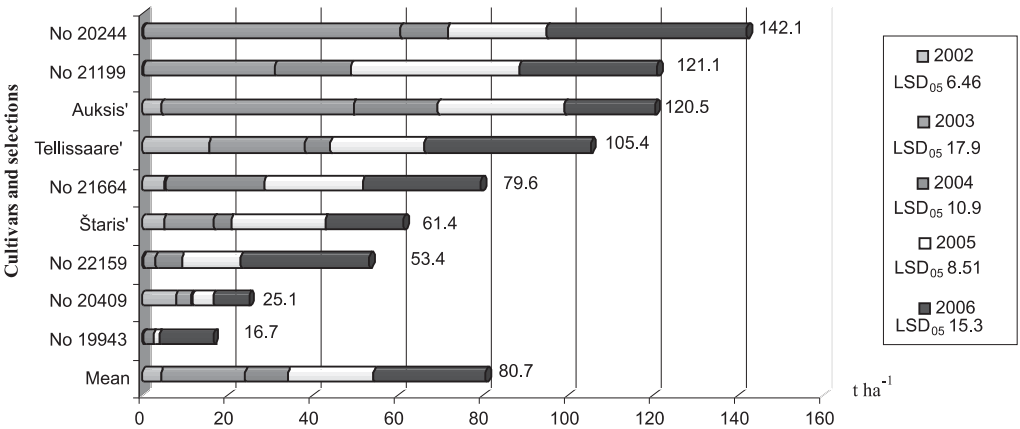

Figure 1. Cumulative yield of apple cultivars and selections (t ha^{-1}), Babtai, 2002-2006

Average yield of apple cultivars and selections ranged from 3.3 to 28.4 t ha^{-1} (Figure 2). Selections No 19943 (3.3 t ha^{-1}), No 20409 (5.1 t ha^{-1}) and No 22159 (10.7 t ha^{-1}) produced lower yields, while cv. 'Auksis' (24.1 t ha^{-1}), selections No 21199 (24.2 t ha^{-1}) and No 20244 (28.4 t ha^{-1}) produced the highest yields.

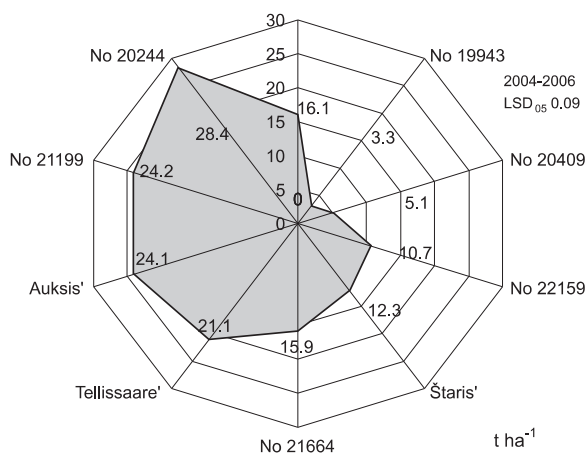

Figure 2. Average yield of apple cultivars and selections (t ha^{-1}), Babtai, 2002-2006

When fruits were graded by size, more than 90% of fruits of cvs. 'Tellissaare', 'Štaris', 'Auksis' and selection No 21664 were Extra class (Table 1). Classes 1 and 2 of apples ranged between 2-56%. Lower amount of Extra class fruits and higher amount of fruits

less than 60 mm had selection No 19943. Selections No 19943, No 20244, No 21199 and cv. 'Štaris' produced some non-standard fruits.

The earliest picking of fruits had selection No 20409 (08.20), latest – No 21199 (09.28), No 22159 (09.29) and No 19943 (09.30) (Table 2). Data of cold storage durability show that fruits of cv. 'Tellissaare' (04.20), 'Štaris' (04.15) and selection No 21199 (04.05) may be stored longest. Selection No 20409 (09.05) was distinguished by a short time of storage life.

On the average during three years the biggest fruits had cv. 'Štaris' (175 g), 'Auksis' (173 g), selections No 22159 (157 g) and No 20244 (154 g) (Table 2). According to fruit evaluation performed by Pomological commission, cv. 'Štaris' (7.6 scores), 'Auksis' (7.4 scores) and selection No 21199 (7.4 scores) produced extremely good appearance. Fruits of cv. 'Auksis' (7.5 scores) and selection No 20244 (7.3 scores) had the best taste in the investigated group of apple cultivars and selections. Cv. 'Auksis' (7.4 scores), 'Štaris' (7.3 scores) and selection No 20244 (7.3 scores) had good general quality (general estimate – involves taste and appearance).

The amount of titratable acidity of all cultivars and selections varied from 0.49 to 1%. The highest amount of titratable acidity was established in selection No 21664 (1%), while essentially lower in No 20244 (0.49%) (Figure 3).

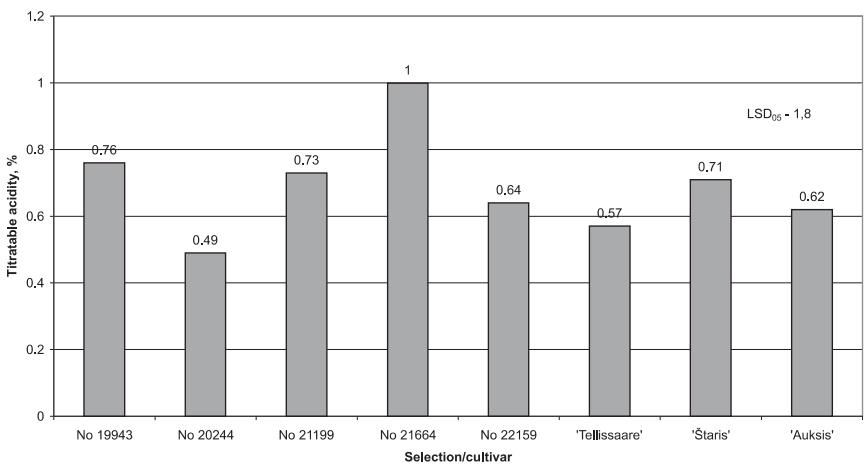

Figure 3. Titratable acidity of apple cultivars and selections (Babtai, 2004–2006)

Soluble solids content in apples ranged from 10.4 to 12.4%. Reliable differences in this parameter were between cv. 'Tellissaare' and cv. 'Auksis' (Figure 4).

The highest amount of juice was established in selection No 19943 (74.8%), while essentially lower in No 21664 (66%) and cv. 'Štaris' (64%). Cvs. 'Tellissaare', 'Auksis', selections No 20244, No 21119 and No 22159 had 64.8-72.2% of apple juice output (Figure 5).

Firmness of apple skin ranged between cultivars and selections. The most thin skin was observed on fruits of No 21199 (248.7 N cm^{-2}) and cv. 'Auksis' (270.7 N cm^{-2}). On the other hand the thickest skin had fruits of No 22159 (454.5 N cm^{-2}) and 'Tellissaare' (379.7 N cm^{-2}) (Figure 6).

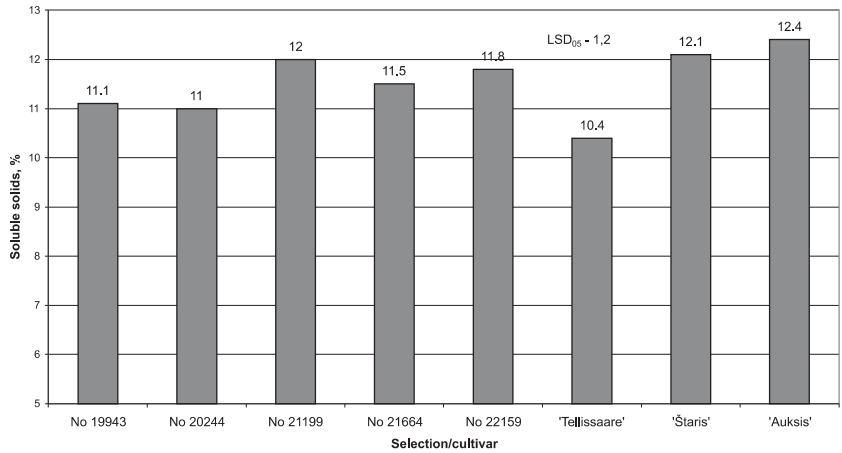

Figure 4. Soluble solids content of apple cultivars and selections (Babtai, 2004–2006)

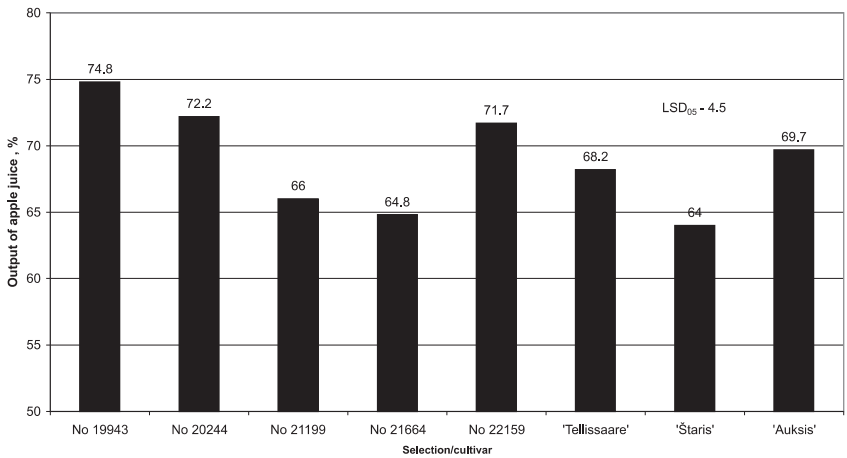

Figure 5. Output of apple juice, % (Babtai, 2004–2006)

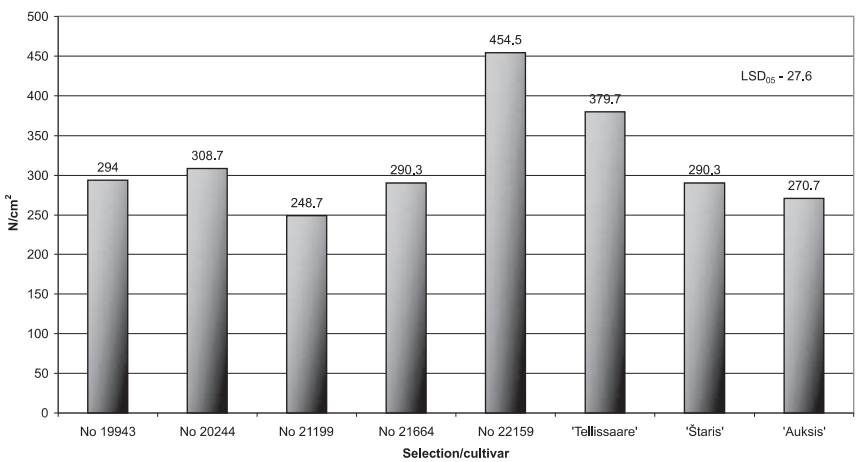

Figure 6. Firmness of apple skin, N cm^{-2} (Babtai, 2004–2006)

The most firm flesh had fruits of No 19943 (93.3 N cm^{-2}) and 'Tellissaare' (93.1 N cm^{-2}), while No 21664 (61.6 N cm^{-2}) and No 21199 (63.3 N cm^{-2}) had the softest flesh (Figure 5).

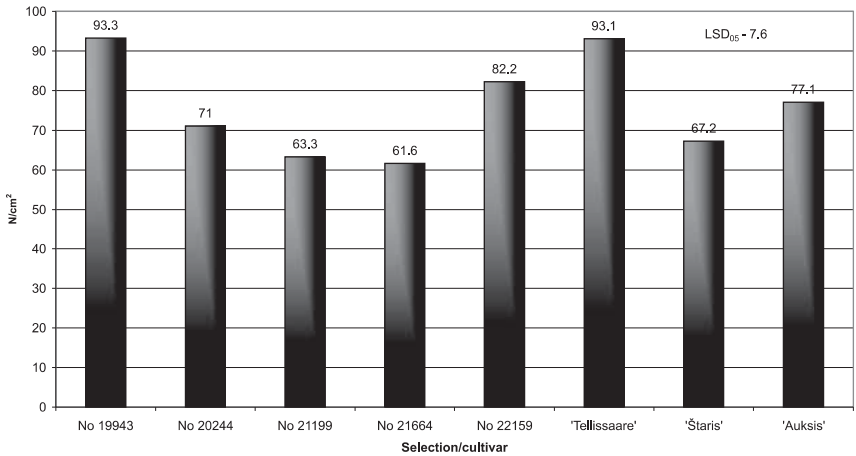

Figure 7. Firmness of apple flesh, N cm^{-2}

The lightest ground colour distinguished fruits of cv. 'Tellissaare' (L* – 77.4), while the darkest – fruits of selection No 21199 (L* – 56.4). The darkest over colour had fruits of selection No 21199 (L* – 30.6). The highest value of ground colour a* coordinates (proportion of red and green colour) had fruits of selection No 21199 (a* – 28.1), the least – fruits of cv. 'Tellissaare' (a* minus 3.7). The highest value of over colour red value a* had fruits of selection No 22159 (a* – 42.2), the least – fruits of cv. 'Tellissaare' (a* – 17.6). The highest ground (b* – 45.2) and over (b* – 37.7) colour of yellow value b* (proportion of yellow and blue colour) had fruits of cv. 'Tellissaare'. Ground colour of chroma distinguished fruits of cv. 'Tellissaare'(C – 45.4) and over colour of fruits – selection No 22159 (C – 46.4). Selection No 21199 had less tone of over colour (h° – 21.3), which means that fruits of this selection were the most red in the group of investigated cultivars and selections.

Discussion

Apple breeders throughout the world tend to improve the productivity of selections. Successful breeding results in an improved population that is superior to the original population in the mean performance and in the performance of the best individuals within it (Fehr, 1987). Investigation data show that different genotypes might have different influence on productivity. Selections No 20244 and No 21199 produced the highest yield, while two others –No 19943 and No 20409 were most unproductive.

Efficient breeding and selection of high quality apple cultivars requires knowledge and understanding. Establishing the optimum harvest date is an important factor in obtaining quality fruits. In our study the earliest harvest of fruits had selection No 20409, latest – No 21199, No 22159 and No 19943. A long storage life is a very important factor in quality evaluation of fruit products offered on the market and guaranteed consumer

acceptance (Ingle et al., 2000). The evaluation shows that fruits of selection No 21199 may be stored longest.

Fruit qualities such as appearance, taste and texture are key factors for the success of a cultivar on the market (Liebhard et al., 2003). During years of investigations the biggest fruits, appearance and taste distinguished selection No 20244. Soluble solids and acidity are other important factors determining eating quality of apples. The best biochemical composition was found in fruits of selections No 21199 and No 21664. Firmness is one of important internal quality attributes in determining fruit maturity and harvest time, and in assessing and grading post-harvest quality of apples (Peng and Lu, 2008). The firmest skin of fruits had selections No 22159 and cv. 'Tellissaare', the firmest flesh – selection No 19943 and cultivar 'Tellissaare'. The highest amount of juice had selection No 19943. The highest parameter of red colour had No 21199.

Conclusions

1. Advanced selections No 20244 and No 21199 can be selected as the best ones among the tested selections.
2. The following apple selections were distinguished for particular characteristics: No 20244 and No 21199 – for yield; No 21199 – for storage life; No 20244 and No 22159 – for fruit taste and quality; No 20244, No 21664, No 22159 – for highest class of fruits; No 20244 and No 22159 – for fruit weight; No 21199 and No 21664 – for biochemical characteristics; No 22159 – for firmness of apple skin; No 19943 – for firmness of apple flesh and best output of apple juice; No 21199 – for fruit colour.

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Table 1. Distribution of apples according to size classes (%)

Babtai, 2004-2006

Selection/ cultivar	Extra class			Class 1 and 2	Non-standard
	65–70 mm	> 70 mm	Total	60–64 mm	< 60 mm
No 19943	28	12	40	56	4
No 20409	64	10	72	28	
No 20244	40	36	76	16	8
No 21199	66	8	74	23	3
No 21664	50	48	98	2	
No 22159	72	10	82	18	
'Tellissaare'	50	44	94	6	
'Štaris'	48	47	95	4	1
'Auksis'	54	40	94	6	

Table 2. Harvest date, end of storage and fruit quality parameters of apple cultivars and selections

Babtai, 2004–2006

Selection/ cultivar	Harvest date (month, day)	End of storage (month, day)	Fruit mass, g	Appearance (scores)	Taste (scores)	General quality evaluation (scores)
No 19943	09.30	12.17	139.6	7.3	6.2	7.0
No 20409	08.20	09.05	126.6	7.0	6.8	6.8
No 20244	09.25	02.20	154.0	7.3	7.3	7.3
No 21199	09.28	04.05	117.6	7.4	7.1	7.2
No 21664	09.23	12.25	148.5	7.0	6.6	6.6
No 22159	09.29	12.20	157.0	7.3	7.2	7.2
'Tellissaare'	09.27	04.20	143.3	7.2	6.6	7.1
'Štaris'	09.25	04.15	175.0	7.6	7.1	7.3
'Auksis'	09.15	02.18	173.0	7.4	7.5	7.4
Mean	09.20	12.16	148.3	7.29	6.93	7.11
LSD_{05}	4.85	10.53	32.8	0.09	0.32	0.11

Table 3. Colour coordinates of apple cultivars and selections

Babtai, 2004–2006

Selection/ cultivar	Lightness L*		Red value a*		Yellow value b*		Chroma C		Hue angle h°	
	G	O	G	O	G	O	G	O	G	O
No 19943	73.8	38.6	5.5	33.6	28.0	14.4	28.6	36.7	78.8	23.2
No 20244	72.3	44.2	6.8	36.1	34.8	19.4	35.5	41.0	78.8	28.3
No 21199	56.4	30.6	28.1	32.0	32.9	12.4	43.4	34.4	49.5	21.3
No 21664	68.6	44.1	2.7	27.7	38.3	22.1	38.4	35.5	85.9	38.6
No 22159	69.3	38.1	13.9	42.2	35.4	19.3	38.1	46.4	68,5	24.7
'Tellissaare'	77.4	64.5	-3.7	17.6	45.2	37.7	45.4	41.6	94.8	64.9
'Štaris'	59.7	39.6	26.8	40.3	25.5	17.5	37.1	44.0	43.6	23.4
'Auksis'	66.6	40.5	13.4	38.5	30.1	17.3	33.0	42.3	66.0	24.2
LSD_{05}	3.27	2.98	1.12	1.58	2.06	2.11	2.22	2.46	1.77	1.86

G – ground colour; O – over colour

SEABUCKTHORN (*HIPPOPHAE RHAMNOIDES* L.) RESEARCH IN BELARUS

Maryna S. SHALKEVICH[1], Dmitriy B.RADKEVICH[1], Anna BIENIEK[2]

[1]The Institute for Fruit Growing
2 Kovalev Street, Samokhvalovichy, Minsk region, 223013 Republic of Belarus,
e-mail: belhort@it.org.by
[2]University of Warmia and Mazury in Olsztyn
ul. Prawocheńskiego 21, 10-757 Olsztyn, Poland

Abstract

The purposes of the research conducted in 1984-2007 in the Institute for Fruit Growing were: to select seabuckthorn cultivars suitable for growing in Belarus and using them as an initial material; to create hybrid fund and domestic cultivars combining high productivity, good taste qualities and a complex of characters, determining suitability for machine harvesting and male cultivars. The research was carried out according to internationally adopted and acknowledged methods and standards.

54 combinations of cross-breeding were carried out. About 50 foreign cultivars were estimated and the cultivars 'Podarok Sadu', 'Botanicheskaya', 'Trophimovskaya', 'Nivelena' were passed to the State Variety Trial and included in the State Register, 22 cultivars and 5 hybrids were selected as initial material.

The examination of wild seabuckthorn plantations at the territory of South Warmia was carried out and 7 forms were selected. About 30 thousands of seedlings were received from single-minded hybridization and open pollination. In 2005 winterhardy male cultivar 'Gaspadar' was recommended for the State Variety Trial. In 2007 the new cultivar 'Plamennaya', created in collaboration with the Russian scientists, was included to the State Variety Trial. The variety is characterized by high productivity (17 t/ha at planting scheme 4x2 m), large fruit (average mass 0.8 g), and valuable chemical composition of fruits. 4 promising hybrids of own breeding (10-02-01-98, 14-24/99, 03-22-00, 06-40-00) were selected for the further research.

Key words: Belarus, breeding, hybridization, initial material, variety trials, seabuckthorn

Introduction

Seabuckthorn is one of the most promising non conventional cultures for the industrial fruit growing. It is determined by annual stable yield, possibility of cultivating on lands of little use for some other crops, by the unique biochemical fruit composition including vitamins, phenols and pectins, macro and micro elements, fatty and amino acids, alkaloids, etc. and also by the unique biochemical leaf composition allowing to receive a wide spectrum of foodstuffs, pharmaceutical and cosmetic preparations.

Seabuckthorn industrial plantations were planted in Russia, Germany, Finland, Poland, China, Canada, Latvia, Estonia and some other countries.

Seabuckthorn introduction into the Republic of Belarus is connected with the activity of Central Botanic Garden of the National Academy of Sciences of Belarus. It was conducted the study of first Russian cultivars, methods of their propagation in the

conditions of the Republic of Belarus were elaborated and first industrial plantations were created by the scientists of this organization. Insufficient winter hardiness of Altai cultivars in the conditions of the Republic of Belarus revealed further along with the unresolved problem of harvesting became the main reasons of decrease in interest to this culture from the side of agricultural producers in the late eighties and in the early nineties of the XXth century.

Nowadays seabuckthorn is cultivated in Belarus mainly in amateur orchards. A positive tendency of the last years is demand increase on planting material from the farmers' side.

Contemporary seabuckthorn assortment is presented by the introduced cultivars of the selection of Botanical garden of Moscow State University such as 'Avgustinka', 'Aromatnaya', 'Botanicheskaya', 'Krasnoplodnaya', 'Nivelena', 'Podarok Sadu', 'Trophimovskaya' and 'Plamennaya' created by the specialists of Nizhniy Novgorod State Agricultural Academy, of All-Russian Scientific Research Institute of Plant Protection and of the Institute for Fruit Growing (Belarus).

Cultivars included into the State Register of varieties and wood and shrubby species (the State Register, 2007) despite the series of advantages (high yield, large fruits, high contain of biologically active substances) don't meet increasing demands. The cultivars included into the State Register are characterized by about the same maturity period that does not allow prolonging the harvesting period which is the most laborious operation in technological cycle. Among them there is no one with a height less than 2.5 m, which demands some additional costs on pruning and creates difficulties while harvesting. Series of cultivars included into the register are characterized by semi-dry character of fruits tearing-off and medium extent of prickliness. Besides, it has been revealed for the last years a significant affection of some cultivars included into the register by wilt and by fruit softening and discoloration (Шалкевич, 2005).

Actuality of the research on the improvement of the existing assortment is evident. This problem shall be solved by two ways: introduction of the best cultivars of foreign selection and creation of domestic ones.

The purpose of the presented research is to select seabuckthorn cultivars suitable for growing in Belarus and using them as an initial material; to create a hybrid fund and domestic cultivars combining high productivity, good taste qualities and a complex of characters, determining suitability for machine harvesting and male cultivars.

Materials and methods

The research was carried out in the experiment field of the Department of small fruits of the RUE "Institute for Fruit Growing" in 1984-2007.

The objects of the research were the following:

In collection orchards and orchards of the initial variety trial of 1982, 1992 and 1997 planting years such as:

- 'Vitaminnaya', 'Dar Katuni', 'Zolotistaya', 'Inya', 'Maslichnaya' 'Novost Altaya', 'Obilnaya', 'Oranzhevaya', 'Panteleevskaya', 'Prevoshodnaya', 'Samorodok', 'Chuiskaya', 'Yantarnaya', K-24, IV-56 – cultivars and hybrids of the selection of the scientific Research Institute of horticulture of Siberia (Barnaul, Russia);

- 'Botanicheskaya', 'Botanicheskaya Luchistaya', 'Vorob'yovskaya', 'Yolochka', 'Zhyoltaya Rannyaya', 'Kaliningradskaya', 'Krasnoplodnaya', 'Lomonosovskaya', 'Mendeleevskaya', Nivelena', 'Otradnaya', 'Podarok Sadu', 'Trophimovskaya', 'Hodnevskaya' and 'Finskaya' which are the cultivars of the selection of Botanic Garden of Moscow State University (MSU);
- 'Zolotoy Shar', 'Mariya', 'Priokskaya', 'Shcherbinka-1', 'Shcherbinka-6', 10/86, 4/87, 15/88, 20/88, 24/88, 29/88, 5/87 (male), 6/87(male) and 7/87(male) belonging to the cultivars and hybrids of the selection of Nizhnij Novgorod State Agricultural Academy;
- seedling under the conventional name 'Grodnenskaya' of the selection of L.S. Tsihotski (Belarus);
- cultivar 'Dorana' of the German selection.

In selection nursery and orchards (1997-2006) about 30 thousands of seedlings received from 54 combinations of crossbreeding and open pollination.

The planting scheme in the collection orchard and orchard of the initial study is 4x2 m, in the selection garden is 4x1 m, in the selection nursery is 0.7 x 0.2 m.

For the economic and useful characteristics estimation there were used "List of descriptors for the species *Hippophae rhamnoides* L." (1993), «Программа и методика селекции плодовых, ягодных и орехоплодных культур» [The program and methods of breeding of fruit, small fruit crops and nuts] (1980, 1995) and "Программа и методика сортоизучения плодовых, ягодных и орехоплодных культур" [The program and methods of varieties testing of fruit, small fruit crops and nuts] (1999).

The prickliness index was being determined by the E.P. Potapov and M.N. Borodachev method (1980).

The extent of pollen germination was being determined by the I.N. Golubinski method (1974). Pollen sowing was conducted in triple replication. The germination extent study was carried out 24 hours after sowing by microscope MBI-3 (10x) use. 100 pollen-grains in three fields of vision were examined.

Biochemical research was conducted in the laboratory of biochemistry and agrochemical analyses of the RUE "Institute for Fruit Growing" and at the chair of processing and chemistry of the plant raw material of the University of Varmia and Mazury (Olsztyn, Poland).

The content of L-ascorbic acid and carotenoids was determined according to the method described in the Polish standards (PN-90/A-75101/11, PN-90/A-75101).

The content of total phenols was determined by the colorimetric method using the Folin-Ciocalteau reagent (AOAC, 1974).

Antioxidant activity of hydrophilic extract was determined as in A.Moure et al., 2001.

Qualitative composition of carotenoids was determined by the HPLC method as described by C. Emenhiser et al. (1995) in S.Chaplicki modification (personal communication).

The results were statistically processed by analysis of variance (Duncan's Multiple Test, p 0.05) by software STATISTICA 6.0.

Results and discussion

Research of foreign cultivars and hybrids. Seabuckthorn collection study at the Institute for Fruit Growing (Belarus) was carried out from the middle eighties of the past century. As a result of the study on basic characters including yield, average fruit mass, fruits chemical composition of 19 cultivars such as 'Botanicheskaya', 'Vorob'yovskaya', 'Vitaminnaya', 'Dar Katuni', 'Zolotistaya', 'Maslichnaya' 'Novost Altaya', 'Nivelena', 'Obilnaya', 'Oranzhevaya', 'Otradnaya', 'Podarok Sadu', 'Prevoshodnaya', 'Samorodok', 'Shcherbinka-1', 'Shcherbinka-6', 'Trophimovskaya', 'Chuiskaya' and 'Yantarnaya' and of 2 hybrids K-24 and IV-56, the availability of cultivating in the conditions of Belarus of the cultivars created in the Botanical Gardens of MSU and an insufficient winter hardiness of the studied cultivars of the selection of the scientific Research Institute of Horticulture of Siberia were revealed. Based on these results there were passed to the State Variety Trial the following cultivars: 'Botanicheskaya', 'Podarok Sadu', 'Trophimovskaya' and 'Nivelena' catalogued later into the State Register (Радюк, 1995).

In 1992-1999 a complex evaluation on winter hardiness, wilt resistance, length and diameter of a one-year shoot, fruit quantity in fruit-bud, productivity, average fruit and seeding mass, pull-out character and fruit stem length was carried out. There were involved 12 cultivars such as 'Botanicheskaya', 'Vorob'yovskaya', 'Zolotoy Shar', 'Lomonosovskaya', 'Mariya', 'Mendeleevskaya', 'Nivelena', 'Otradnaya', 'Podarok Sadu', 'Priokskaya', 'Trophimovskaya' and 'Yolochka' and 7 promising hybrids created by V.A. Phephelov (Nizhnij Novgorod, Russia) which are 10-86, 4-87, 20-88, 29-88 ('Plamennaya'), 5-87 (male), 6-87 (male), 7-87 (male). As a result of investigation it was proved a promise of the cultivars created on the base of Baltic seabuckthorn in Botanic Garden of MSU. The cultivar 'Plamennaya', characterized by high productivity (17 t/ha at planting scheme 4x2 m), large fruit (0.8 g), and valuable chemical composition of fruits was passed to the State Variety Trial; initial material for further breeding was selected (Шалкевич, 2001).

The detailed research of a fruit chemical composition was carried out; the stability of different characters was determined; the cultivars for breeding on fruit quality were selected (Nesterowich et al., 1999; Bieniek et al., 2001; Шалкевич, 2001).

In 1998-2006 the new collection including 12 cultivars was estimated. The results of comparative estimation of some characters of the cultivars are presented in Table 1.

As results showed the cultivars differ on prickliness capacity. Among the tested cultivars there were no thornless ones.

All tested cultivars were inferior to standard 'Plamennaya' significantly in total yield. 'Zhyoltaya Rannyaya' was characterized by higher total yield. The low yield of the cultivars 'Inya'and 'Prevoshodnaya' is explained by low winter-hardiness. The low yield of the 'Krasnoplodnaya' is a result of a strong affection by wilt.

In Belarus conditions it is necessary to make an evaluation of new high wilt resistant cultivars, in particular, created by V.T. Kondrashov (2004) and V.A. Phephelov (2005).

The cultivars differed significantly on their average fruit mass. 'Dorana' was characterized by small fruit (less than 0.5 g) and doesn't make any practical use. This cultivar may be used as an ornamental one only. 'Inya', 'Panteleevskaya' and 'Krasnoplodnaya' didn't differ significantly from a standard cultivar and had large fruits.

All the rest cultivars were characterized by medium-sized fruits (0.5-0.7 g), although the differences within the group were significant.

Pull-out character is one of the most important criterion of suitability for machine harvesting. As S.N. Khabarov and V.D. Bartenev (2002) noted the cultivars with the pull-out force 1.2-1.5 H are suited for machine harvesting. In 2005-2006 the pull-out force of the 15 cultivars of different origin were determined (Шалкевич, Радкевич, 2007). The cultivar 'Mariya' had a minimum pull-out force 1.55 H and was selected as a source of the criterion.

In result of the estimation of chemical composition of seabuckthorn fruit of 26 varieties, carried out in 1995-2006, it was determined that all of them were characterized by the low ascorbic acid content (<100 mg/100g) and low total sugar content (< 5%). This fact is the evidence of a study necessity in Belarus condition of cultivars with high ascorbic acid content.

The quantitative and qualitative composition of carotenoids estimation of the cultivars 'Krasnoplodnaya', 'Mariya', 'Panteleevskaya', 'Plamennaya', 'Prevoshodnaya', 'Zhyoltaya Rannyaya' was carried out. The cultivar 'Krasnoplodnaya' was characterized by the maximum content of total carotenoids (28.163 mg/100g). 13 carotenoids were detected (Чаплицки и др., 2004).

The content of L-ascorbic acid, total phenols and antioxidant activity of hydrophilic extract of these cultivars was determined. The extract obtained from 'Prevoshodnaya' fruits possessed the best antioxidant activity (13.04±0.02 μmol DPPH·/1 g fruit) due to the highest total phenol and L-ascorbic acid content (Шалкевич и др., 2004).

Creation and estimation of hybrid fund. The first hybrids were received from the open pollination of the cultivars 'Botanicheskaya', 'Podarok Sadu', 'Otradnaya', Trophimovskaya by A.I. Batchylo in 1992. All female hybrids were characterized by small fruit weight, bad taste and high winter-hardiness.

54 combinations of cross-breeding were carried out in 1998-2007. 22 cultivars and 5 hybrids ('Botanicheskaya', 'Zhyoltaya Rannyaya', 'Nivelena', 'Trophimovskaya', 'Mariya', 4/87, 6/87 etc.) were used as initial material. About 30 thousands of seedlings were estimated at the selection nurseries and orchards in 1997-2006.

The promising hybrids 10-02-01-98, 14-24/99, 03-22-00, 06-40-00 were selected for further primary study (Table 2).

All selected hybrids were characterized by winter-hardiness, dry pull-out character and had no visual wilt symptoms. Hybrids 10-02-01-98, 06-40-00 had very low height (<2.1 m).

Moreover, the hybrids 10-07-01-98, 04-40-00, 11-28-00, 03-47-00, 25-47-00 were selected for use as initial material.

Since seabuckthorn is a diclinous plant the success in breeding depends on male forms as well. From the hybrid fund, created in 1992, the promising male forms 01-43-95, 16-01-95, 11-04-96, 04-17-96 were selected for further estimation. The hybrids were characterized by winter-hardiness and guaranteed good pollination of the female cultivars. It is necessary to note, that no symptoms of wilt were detected in the estimation stage.

The primary study of the male hybrids was carried out in 1998-2005. Some characters of the hybrids are showed in Figures 1-3.

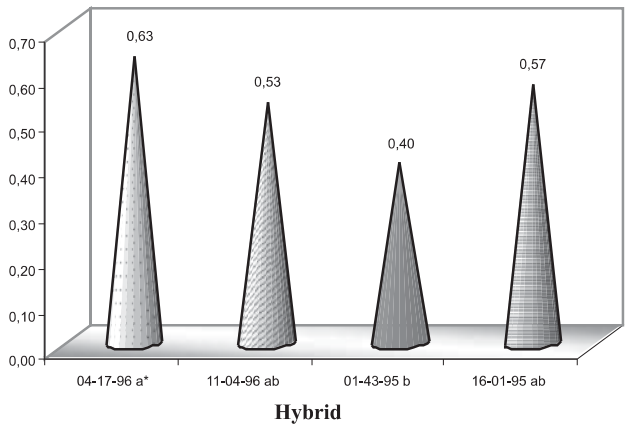

Figure 1. Prickliness index of male seabuckthorn hybrids

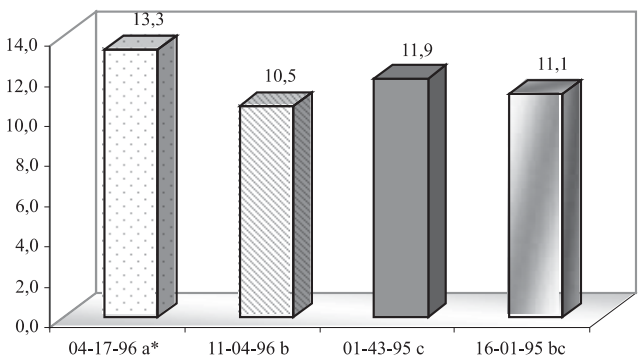

Figure 2. Average number of reproductive buds per 10 cm of seabuckthorn hybrid shoot, pcs.

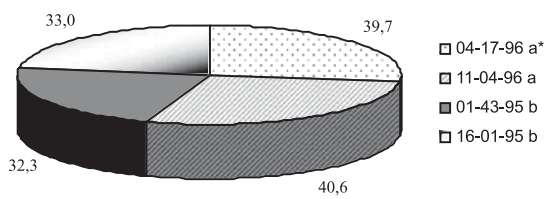

Figure 3. Pollen germination of seabuckthorn hybrids, %

* Means of hybrids with the same letter are not significantly different according to Duncan's Multiple Test at p 0.05

All hybrids are winter hardy. Wilt symptoms were observed at all tested hybrids, however the hybrid 11-04-96 was affected less than other ones.

The cultivar 'Gaspadar' (11-04-96) was passed to the State Variety Trial.

It is well known that the Baltic seabuckthorn forms are promising for breeding work (Albrecht, 2003; Rumpunen, 2004; Смертин, 2006). To introduce new parental forms into the breeding process, the examination of wild seabuckthorn plantations at the territory of South Warmia of Poland was carried out in 2006. 7 female and 1 male forms were selected as initial material for breeding. All selected female forms were

characterized by the absence of visual wilt symptoms, high productivity and dry tearing-off of fruits. The form 'Shossejnaya-3' was characterized by the maximum fruit stem length (6.4 mm), whereas the form 'Parkovaya' had the minimum value of the pull-out force (1.8 N). A winter hardy male form with the absence of visual fading symptoms and low degree of prickliness was selected (Shalkevich et al., 2007).

Conclusions

1. As a result of the research 5 seabuckthorn cultivars 'Botanicheskaya', 'Podarok Sadu', 'Trophimovskaya', 'Nivelena', 'Plamennaya' were passed to the State Variety Trial and included later into the State Register. 22 foreign cultivars and 5 hybrids were selected as initial material. It was concluded that there is a necessity to perform a study of cultivars with high resistance to wilt and high sugar and ascorbic acid content in Belarus condition.
2. Hybrid fund including about 30 000 hybrids from 54 combinations of cross-breeding and open pollination was created. The promising hybrids 10-02-01-98, 14-24-99, 03-22-00, 06-40-00 were selected for further primary study.
3. Winter-hardy male cultivar 'Gaspadar' was passed to the State Variety Trial and was recommended for commercial plantation.
4. To shorten the breeding period it is necessary to improve the scheme of the breeding process and to work out some effective selection methods of wilt resistant samples at the early development stages.

Acknowledgments

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Table 1. Comparative characteristic of seabuckthorn cultivars (2000-2006)

Variety	Prickliness capacity	Total yield, kg/tree	Average fruit mass, g	Pull-out character	Pull-out force, H
'Plamennaya' (st.)	medium	65.4	0.76g	semi-dry	2,20rtu
'Botanicheskaya Luchistaya'	weak	20.8	0.58h	dry	2,29r
'Grodnenskaya'	medium	32.5a	0.48hk	semi-dry	2,50
'Inya'	weak	4.0b	0.76gm	dry	—
'Panteleevskaya'	medium	36.7c	0.78gmn	semi-dry	2,30ru
'Prevoshodnaya'	weak	6.3b	0.67ghmp	dry	—
'Zhyoltaya Rannyaya'	weak	55.9	0.67ghmpq	wet	1,80
'Kaliningradskaya'	weak	47.9	0.45k	dry	2,06s
'Krasnoplodnaya'	weak	7.3b	0.79gmn	dry	2,11st
'Finskaya'	medium	30.9a	0.45k	dry	2,32ru
'Hodnevskaya'	weak	36.6c	0.64hpq	dry	—
'Dorana'	strong	—	0.29	—	—

* Means with the same letter(-s) within columns are not significantly different according to Duncan's Multiple Test at p 0.05

Table 2. Comparative characteristic of seabuckthorn hybrids

Hybrid	Plant height, m	Prickliness capacity	Average fruit mass, g	Pull-out force, H	Fruit color	Pull-out character
10-02-01-98	1.8	weak	0.65a	1.55b	yellow-orange	dry
14-24-99	2.3	medium	0.69a	1.84	orange-red	dry
03-22-00	3.2	medium	0.88	1.55b	dark yellow	dry
06-40-00	1.5	medium	0.51	2.15	yellow-orange	dry

* Means with the same letter within columns are not significantly different according to Duncan's Multiple Test at p 0.05

GROWTH OF YOUNG (THREE-YEAR-OLD) 'REGINA' SWEET CHERRY TREES GRAFTED ON NINE CLONAL ROOTSTOCKS

Miroslaw SITAREK and Elzbieta ROZPARA

Research Institute of Pomology and Floriculture,
Pomologiczna 18, 96-100 Skierniewice, Poland;
e-mail: msitarek@insad.pl

Abstract

In a field experiment, 'Regina' sweet cherry trees grafted on rootstocks of German selection: 'GiSelA 5', 'GiSelA 3', 'GiSelA 6', 'Piku 1', 'Piku 3', 'Piku 4', as well as those on the Italian rootstock 'Victor', and the Russian rootstocks 'LC-52' and 'VSL 1' were investigated. 'Regina' trees on 'GiSelA 5' were regarded as the control combination. The trees were planted in a grey-brown podzolic soil at a spacing of 4.5 x 2.5 m. The data collected in the third year after planting included tree vigour (expressed as trunk cross-sectional area), and the number and length of one-year-old shoots.

The results revealed that the most dwarfing among the rootstocks tested was 'GiSelA 3'. In terms of growth, 'Piku 1' reached an intermediate level between 'GiSelA 5' and 'GiSelA 3'. No significant differences in trunk cross-sectional area between 'Piku 4', 'Victor', 'LC-52', 'VSL 1', 'GiSela 6' and 'GiSelA 5' were found. 'Piku 3' proved to be the most vigorous rootstock in this trial.

The number and total length of one-year-old shoots on the sweet cherry trees were also affected by the rootstock used. The trees on 'LC-52' had on average 150.7 one-year-old shoots while those on 'Victor' only 85.2. No shoots longer than 60 cm were found on the trees grafted on 'GiSelA 3'. Therefore, those trees had the lowest total length of one-year-old shoots. In terms of vegetative performance measured as the total length of one-year-old shoots 'Piku 3' was the leading rootstock.

Key words: growth, length of shoot, 'Regina', rootstock, sweet cherry

Introduction

The main problem in sweet cherry (*P. avium* L.) production in Poland and other European countries over the last decades was the large tree size, which increased the cost of management activities, especially harvesting. Many investigations have been carried out to find a solution in order to reduce the growth vigour of sweet cherry trees in a way similar to that used for apple trees, i.e. using dwarfing or semi-dwarfing rootstocks. The latest experiments show that among the Piku and GiSelA series of cherry rootstocks bred in Germany, there are several rootstocks that are capable of reducing tree size and also easily adaptable to different soil conditions (Azarenko and McCluskey, 1998; Franken-Bembenek, 1998, 2004 and 2005; Hildensegen, 2004; Sitarek et al., 2005; Stehr, 2005). Researchers from Italy and Russia have also reported on very promising, new rootstocks for sweet cherry trees – 'Victor', 'LC-52' and 'VSL 1' (Battistini and Battistini, 2005; Eremin et al., 2000).

Breeding programmes and selection of dwarfing rootstocks for sweet cherry trees has not been conducted in Poland. Therefore, any progress in this respect is possible only by using rootstocks of foreign selection. Trials to evaluate the most interesting

rootstocks in Polish growing conditions are coordinated mainly by the Research Institute of Pomology and Floriculture in Skierniewice. The first such experiment, with 'P-HL' rootstocks, was set up in 1988 (Sitarek et al., 1999). This paper presents preliminary results of tree growth obtained in the latest trial with nine clonal rootstocks for sweet cherry trees.

Materials and methods

In a field experiment, 'Regina' sweet cherry trees grafted on rootstocks of German selection: 'GiSelA 5', 'GiSelA 3', 'GiSelA 6' (all three *P. cerasus* L. 'Schattenmorelle' x *P. canescens* L.), 'Piku 1' (*P. avium* L. x *P. canescens* L. x *P. tomentosa* L.), 'Piku 3' (*P. pseudocerasus* L. x (*P. canescens* L. x *P. incisa* L.), 'Piku 4' (*P. canescens* L. x *P. tomentosa* L.) x *P. avium* L.), as well as the Italian rootstock – 'Victor' (*P. cerasus* L.), and the Russian rootstocks 'LC-52' (*P. cerasus* L. 'Schattenmorelle' x (*P. cerasus* L. x *P. maacki* Rupr.) and 'VSL 1' (*C. fruticosa* (Pall.) G. Waron.) x *C. lannesiana* Carr.) were investigated. 'Regina' trees on 'GiSelA 5' were regarded as the control combination. One-year-old sweet cherry trees were produced in the nursery of the State Instructional and Experimental Station in Oppenheim, Germany, and then planted at the Experimental Station in Dabrowice, near Skierniewice (central part of Poland), in the spring of 2005. All maidens were uniform and of very high quality. The trees were planted in a grey-brown podzolic soil at a spacing of 4.5 x 2.5 m, in a random arrangement (6 replications x 1 tree per plot). Thus, the total number of 'Regina' sweet cherry trees on each rootstock was six. In the orchard, a drip irrigation system was installed for applying water during the vegetation season because the average annual precipitation in the area is only about 450 mm. In 2005, the soil was kept free from weeds by mechanical cultivation. During the following years, soil management included frequent mowing of the grass in the alleyways combined with the maintenance of 1-m-wide herbicide strips along the tree rows. Herbicides and fertilizers were applied in accordance with the standard recommendations for commercial sweet cherry orchards. The trees were trained according to the Vogel Central Leader system.

The data collected in the third year after planting included tree vigour (expressed as trunk cross-sectional area), and the number and length one-year-old shoots.

The results were processed using a statistical analysis of variance. To evaluate the significance of the differences between means, Duncan's Multiple Range test was employed at $P = 0.05$.

Results

The results revealed that the most dwarfing among the rootstocks tested was 'GiSelA 3'. Three-year-old 'Regina sweet cherry trees grafted on this rootstock had the smallest trunk cross-sectional area (Table 1 and Figure 1). In terms of growth, 'Piku 1' reached an intermediate level between 'GiSelA 5' and 'GiSelA 3'. No significant differences in trunk cross-sectional area between 'Piku 4', 'Victor', 'LC-52', 'VSL 1', 'GiSela 6' and 'GiSelA 5' were found. 'Piku 3' proved to be the most vigorous rootstocks.

The number and total length of one-year-old shoots on the sweet cherry trees were also affected by the rootstock used. The trees on 'LC-52' had on average 150.7 one-year-old shoots while those on 'Victor' only 85.2. No shoots longer than 60 cm were found

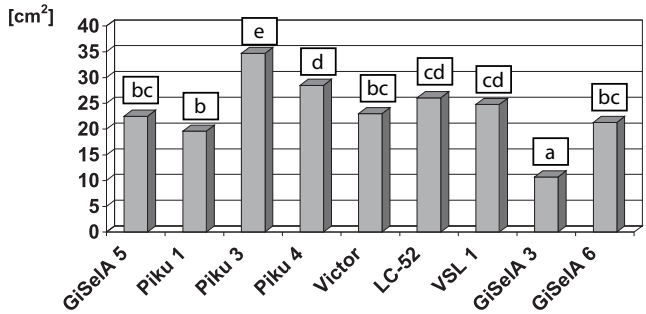

Figure 1. Effect of the rootstocks on the annual increase in trunk cross-sectional area of 'Regina' sweet cherry trees (2006-2007).
(Bars with the same letter are not significantly different at P = 0.05).

on the trees grafted on 'GiSelA 3'. Therefore, those trees had the lowest total length of one-year-old shoots. In terms of vegetative performance measured as the total length of one-year-old shoots 'Piku 3' was the leading rootstock. Detailed data on the growth of shoots on young 'Regina' sweet cherry trees in relation to the rootstock used are presented in Table 1.

Discussion

After 3 years, our results show the value of 'GiSelA 3' and 'Piku 1' rootstocks for reducing the growth vigour of sweet cherry trees. The most vigorous among the rootstocks tested was 'Piku 3'. The trunk cross-sectional area of the trees on 'Piku 3' was by about 19% bigger than that of the trees on 'Gisela 5'. This is in agreement with the results obtained by Hilsendegen (2004) and Stehr (2005). The vigour of the other rootstocks tested was very similar to that of 'GiSelA 5' used as the control in this trial.

In the literature, the information on the rootstocks 'LC-52' and 'VSL 1' is very limited because up till now they have been tested only in Russia. Eremin et al. (2000) report that these rootstocks are very promising and, in comparison with Mazzard seedlings, reduce tree growth by about 40%. The first results on the Italian rootstock 'Victor' correspond with the results obtained earlier by Battistini and Berini (2004). 'Victor' may thus prove to be a valuable semi-dwarfing rootstock for cherry production in Poland.

Conclusions

The results obtained after three growing seasons indicate that:

1. Controlling the vigour of sweet cherry trees with 'GiSelA 3' and 'Piku 1' rootstocks is very effective. Trees grafted on these rootstocks grow slower than on 'GiSelA 5'.
2. The most vigorous among the rootstocks tested was found to be 'Piku 3'.
3. In terms of their influence on the growth of 'Regina' sweet cherry trees, the rootstocks 'Piku 4', 'Victor', 'LC-52', 'VSL 1' and 'GiSelA 6' have the same value as 'GiSelA 5'. However, the final conclusion on the usefulness of these rootstocks in Polish growing conditions will depend on their effect on yielding and fruit quality.

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Table 1. Trunk cross-sectional area (TCSA), mean number and length of one-year-old shoots of 'Regina' sweet cherry trees grafted on different clonal rootstocks. The trees were planted in the spring of 2005.

Rootstocks	TCSA 2007		Mean number of one-year-old shoots in 2007 [pieces/tree]				Length of one-year-old shoots in 2007 [m/tree]			
	[cm²]	[% of GiSelA 5]	5-30 cm	30-60 cm	> 60 cm	Total	5-30 cm	30-60 cm	> 60 cm	Total
GiSelA 5	50.3 c*	100.0	24.0 c	87.0 de	17.8 b	128.8 c	5.1 c	37.7 d	12.5 a	55.3 cd
Piku 1	37.3 b	74.2	23.7 c	67.1 c	11.4 ab	102.2 b	5.2 c	29.7 bc	8.1 a	43.0 b
Piku 3	59.7 d	118.7	8.0 ab	66.4 c	34.0 cd	108.4 b	2.0 a	34.6 cd	28.6 bc	65.2 d
Piku 4	53.9 cd	107.2	9.9 ab	70.0 c	26.9 c	106.8 b	2.5 a	33.8 cd	22.4 b	58.7 cd
Victor	46.4 c	92.2	5.4 a	52.0 b	27.8 c	85.2 a	1.0 a	25.8 b	23.5 b	50.3 bc
LC-52	49.1 c	97.6	12.7 b	93.5 de	44.5 d	150.7 c	2.9 ab	49.7 e	34.7 c	87.3 e
VSL 1	53.4 cd	106.2	22.4 c	81.1 cd	44.4 d	147.9 c	4.7 bc	39.8 d	36.4 c	80.9 e
GiSelA 3	28.5 a	56.7	58.2 c	39.9 a	—	98.1 ab	12.2 d	18.4 a	—	30.6 a
GiSelA 6	48.2 c	95.8	23.7 c	101.6 e	8.9 a	134.2 c	5.5 c	47.4 e	6.9 a	59.8 cd

Explanation: * Means followed by the same letter are not different at P = 0.05

INVESTIGATION OF RASPBERRY CULTIVARS AND HYBRIDS IN LATVIA

Sarmīte STRAUTIŅA, Kaspars KAMPUSS, Inta KRASNOVA

Latvia State Institute of Fruit-Growing,
Graudu 1, Dobele, Latvia, LV-3701
e-mail: sarmite.strautina@lvai.lv

Abstract

Raspberry in Latvia is the third most important berry crop after strawberry and black currant. The area of raspberry in 2006 was 250 ha. On the other hand, the average yield of raspberry is only 3 t per ha. There are several reasons of low yield: adverse conditions of wintering, poor adaptation and low productivity of cultivars, bad cultivation conditions. To improve the assortment of raspberry cultivars, we investigated 9 cultivars and hybrids from several sources during the years 2003-2007. Yield, average weight of 100 berries and biochemical content of berries were investigated. Big difference of climatic conditions was observed between the years of the investigations. Cultivar 'Lina' had the highest yield per bush – 1.2 kg. The highest average weight of 100 berries had cultivars 'Ina' – 386 g and 'Tulameen' – 352 g. Cultivar 'Lina' had the highest content of total phenolics 245 mg/100g. The cultivars 'Tulameen', 'Meeker', and 'Schőnemann' were the least winter-hardy and had low yields.

Key words: cultivars, fruit quality, raspberry, *Rubus*, winter-hardiness, yield

Introduction

Raspberry is a traditional berry crop in Latvia. The wild raspberry, *Rubus idaeus* L., is widespread in forest openings. As a cultivated crop, raspberry has been grown in gardens from nineteenth century (Zigra, 1803). First cultivars were introduced from West Europe. The winter-hardiness of these cultivars was not high enough, and, after cold winters, the plantations were strongly damaged. After the Second World War, most of new cultivars were introduced from Russia and other parts of the former Soviet Union. The positive trait of these cultivars is a high resistance to low winter temperature, but often they are not resistant enough to temperature fluctuations in the second part of winter. Other negative traits are that most of them haven't berries big enough or the berries are too soft.

Although raspberries are a popular berry crop in Latvia, the growing of them is problematic, because of poor adaptation to climatic conditions, especially temperature fluctuations in the second part of winter, growing without irrigation, and low quality of plant material.

There are only few raspberry plantations larger than 10 ha, situated in several parts of Latvia with different climatic conditions. The commercial cultivars in Latvia are 'Ottawa', 'Skromnitsa', 'Norna', 'Sputnitsa', 'Kirzach', 'Tomo', 'Novokitaevskaya, and 'Bulgarski Rubin'. Cultivar 'Ottawa' is known as the best adapted; it yields well every year in all regions of Latvia. However, berries of this cultivar are small, though high quality. Berries are mainly used for fresh consumption, therefore good appearance and resistance to transportation is important.

None of the breeding programs in Western and Eastern Europe (Daubeny, 2002; Finn & Knight, 2002 ; Казаков, 2001) can produce cultivars, completely adapted to Latvian climate and market requirements, therefore in addition to introduced cultivar evaluation, a local breeding program is running (Strautina & Lacis, 2000).

Material and Methods

During the years 2004-2006, nine raspberry cultivars and hybrids from several sources were evaluated for yield, winterhardiness, average weight of 100 berries, and total phenolic content in berries. The experiment was designed in randomized plots, in three replicates. Each replicate consisted of ten plants. The plants were spaced 0.5x3.0 m. Plantation was not irrigated before 2006. Yield was measured in g per plot, winter-hardiness was evaluated after winter 2006/2007 in scores 1 – 9, where 1 means no damage and 9 – completely dead stems. Total phenolic content was estimated by means of Folin-Ciocalteu reagent (Singleton et al.,1999). Total phenolics were analysed in widely commercially grown in Latvia cultivars or in those potentially perspective in future.

Meteorological conditions were very different in the years of the experiment. The best conditions for over-wintering were in the winter of 2003/2004. Minimal temperature in January was -20.4 °C, which lasted for a short time. Over-wintering of raspberries in 2004/05 was badly influenced by the decrease of temperature to -21 °C in the first decade of March, after a prolonged warm period in January and February. The most unfavorable conditions were in winter 2006/2007. Sharp decrease of temperature to -24.7 °C was observed in February 6–8, when raspberries had finished the endo-dormancy period.

Results and Discussion

Raspberry stems were damaged by the frost in winter of 2006/2007 (Figure 1).

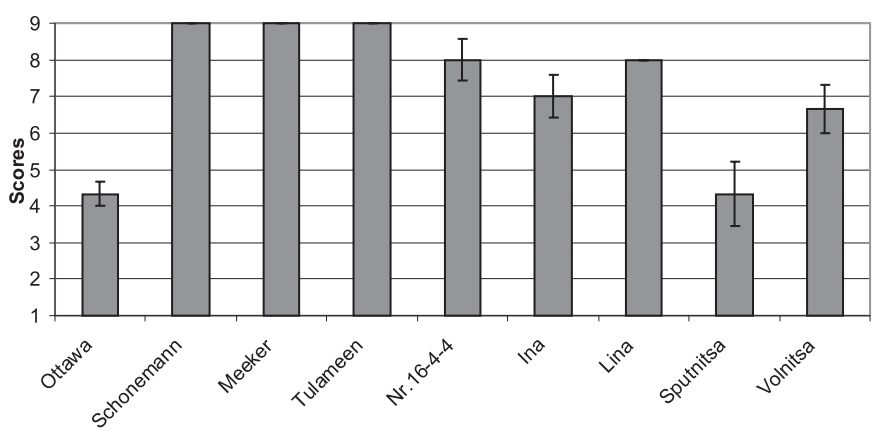

Figure 1. Winter frost damage of raspberries in 2006/2007, scores.
Error bars represent standard error of mean from replications in the given year

The cultivars 'Ottawa' and 'Sputnitsa' were significantly less damaged by winter frost in year 2006, average 4.3 scores, whereas stems of 'Schőnemann', 'Meeker', and 'Tulameen' were completely dead.

The cultivar 'Lina' had significantly higher average yield (1.2 kg per plant) in 2004–2005 than any other described cultivar. Cultivars 'Ottawa', 'Ina' and Nr.16-4-4 had also good average yields, 0.97, 0.96 and 0.78 kg per bush, respectively (Figure 2). 'Volnitsa', 'Schőnemann', 'Meeker', and 'Tulameen' had the lowest yield, which can be explained by less adaptation to Latvian climate (Figure 1).

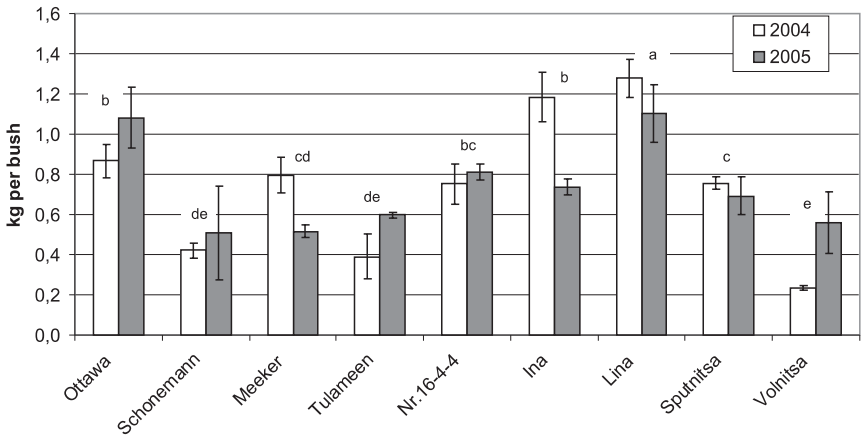

Figure 2. Average raspberry yields, kg per plant. Error bars represent standard error of mean from replications in the given year
Cultivars, marked with the same letter, are not significantly different (p = 0.05) from each other; average from 2004 and 2005.

No significant differences were found between years, however, significant interaction (p=0.013) cultivar × year was found: 'Ottawa' and 'Volnitsa' had higher yields in 2005, whereas 'Meeker', 'Ina', and 'Lina' – in 2004. So, growing conditions influence productivity of the cultivars differently, and growing of several different cultivars can be recommended for regularly yielding plantations.

Significant differences in the mass of 100 berries were found between years and cultivars (Figure 3). Berry mass was higher in 2004, which can be explained mostly by the better moisture conditions (plantation was not irrigated in this experiment) – total precipitation in May, June, and July of 2004 was higher than during this period in 2005 (192 mm and 161 mm, respectively). This difference was especially explicit in June (97 mm in 2004 and 48.7 mm in 2005).

The highest average mass of 100 g berries had cultivars 'Ina' (386 g) and 'Tulameen' (352 g), though it was mainly due to outstandingly high berry mass in 2004 (501 and 425 g, respectively), not in 2005. Therefore we can assume that the latter cultivars have a potential for large berries, and 'Ina' also high productivity, if growing conditions are optimal.

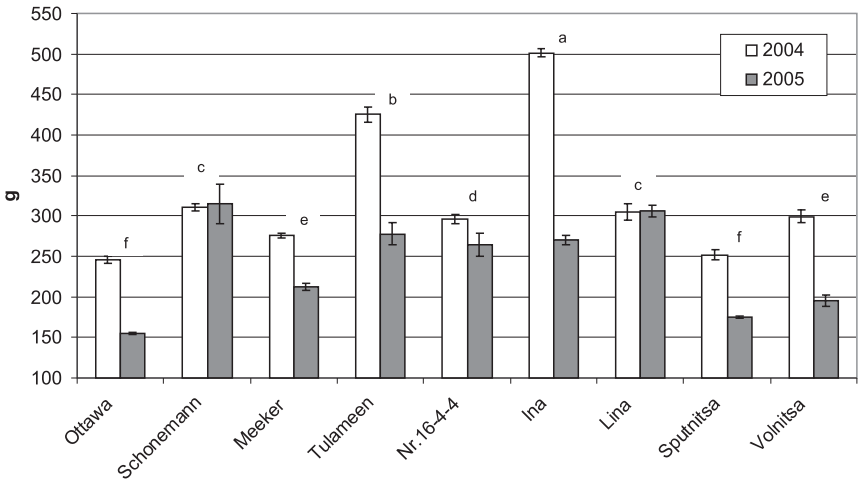

Figure 3. Average mass of 100 berries, g
Error bars represent standard error of mean from replications in the given year
Cultivars, marked with the same letter, are not significantly different (p = 0.05)
from each other; average from 2004 and 2005.

No correlation was found between yield and mass of 100 berries in this experiment.

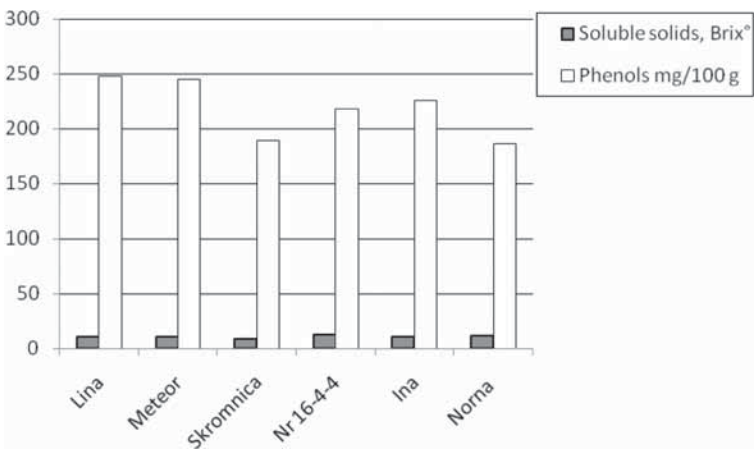

Figure 4. Average content of soluble solids and total phenolic in fresh berries in 2005

The cultivars 'Lina', 'Meteor' and 'Ina' had the highest content of phenolics – more than 226 mg/100g of fresh berries (Figure 4), therefore they can be useful for production of functional foods.

Conclusions

1. The cultivars 'Tulameen', 'Meeker', and 'Schőnemann' had the lowest winter-hardiness and therefore had low yields. These cultivars are not suitable for wide growing in Latvia.

2. The cultivar 'Lina' had the highest average yield per bush – 1.2 kg.
3. The highest average mass of 100 berries had the cultivars 'Ina' – 386 g and 'Tulameen' – 352 g. These cultivars have a potential for larger berries, and 'Ina' also has high productivity, if growing conditions are optimal.
4. The cultivar 'Lina' had the highest content of phenolics: 245 mg/100g.
5. The cultivar 'Ina' has to be included in wider commercial experiments and can be used as a parent plant in breeding of new cultivars because of its large fruits, productivity, and valuable chemical composition.

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THE BREEDING OF APPLE ROOTSTOCKS IN POLLI – FROM CROSSES OF 1981

Toivo UNIVER, Neeme UNIVER, Krista TIIRMAA

Estonian University of Life Sciences, Institute of Agricultural and Environmental Sciences, Polli Horticultural Research Centre, Polli, 69108, Karksi-Nuia, Viljandi County, Estonia
e-mail: neeme.univer@emu.ee

Abstract

In Estonia the apple rootstock breeding programme was started in 1954. 10 clones released for state economic testing. In 1981 A. Veidenberg began new crossing series with rootstocks. His goal was to obtain dwarf and semi-vigorous rootstocks with winter-hardy and good rooting ability of shoots. He used E53 and E75 as female parents and crossed them with E20, E28, E39, E53, E75 and MM106. Also some seeds were collected from open pollinated E53, E75 and MM106. From 4747 seeds that were sown, in total 2219 seedlings (46.7%) resulted. The average rooting of all seedling families was 3.6 (on a scale from 1 to 5). However, 232 specimens (10.5%) stood out with their ability to form adventitious roots and were planted in stoolbeds in order to study their propagation. The better genotypes formed 12.4-30.1 shoots per mother plant on the 8-year average. But rooting of these selections was only 1.6-2.5 points and because of that further investigation in the orchard was abdicated. In cross combinations E75 × MM106, E53 × E75 and E75 × E28 there occurred genotypes which formed numerous shoots in stoolbed propagation.

Key words: apple, propagation, rootstocks, rooting ability, stoolbeds

Introduction

Modern fruit growing is based on composite fruit trees consisting of two partners; the scion cultivar and rootstock type. Each rootstock has its own distinct characteristics. Depending on which rootstock is used, apple trees may be broadly classified into 4 categories: dwarf, semi-dwarf, semi-vigorous and vigorous or standard size. Currently, a major requirement is a potential for "dwarfing". Trees on dwarfing rootstock will begin to come into fruit after 2-3 years, reaching full cropping capacity after 5-6 years. Dwarf rootstocks have the added advantage of being very precocious, with high yield efficiency (Wertheim, 1998).

There are 20 countries where apple rootstock breeding or clonal selection has been carried out, resulting in around 240 rootstocks (Hrotko, 2007). Many of the apple trees currently in production throughout the world were bred and released by East Malling (Webster et al., 2007). The low winter hardiness of English rootstocks have been prompted to start a breeding programs in Poland (Czynczyk and Jakubowsky, 2007) and in Russia (Potapov, 1999; Kuldoshin, 1999) to obtain dwarfing rootstocks suitable for cold climate zones.

In Estonia, where severe winters may occur, roots, root collar and graft union of rootstocks should be winter hardy. In Estonia apple rootstock research was started in 1928. It was found that EM-type rootstocks were not sufficiently winter-hardy in Estonia (Mätlik, 1939). The apple rootstock breeding programme in Estonia was started

by J. Palk in 1954. His goal was to obtain rootstocks with winter-hardy and well-rooting shoots. Palk selected 87 clonal rootstocks and marked them by the letter E (Estonia). 10 clones (E19, E20, E26, E28, E37, E53, E56, E63 ja E75) were released for state economic testing. From these E20, E53, E56 and E75 were selected for production in nurseries (Veidenberg, 1985). The seedlings bred by J. Palk were not completely satisfactory. These clonal rootstocks were significantly more winter hardy, gave more shoots and rooted better in mother plantations (Univer, 2000), but among them only E75 is characterised by weaker growth (Haak, 2003). For this reason, Arvo Veidenberg started a new crossing series in 1981, 1982 and 1983. His goal was to obtain dwarf and semi-dwarf rootstocks with winter-hardy and well-rooting shoots.

This study includes data of 1981 rootstock crossings from 1983-1995 scientific reports of Polli Research Institute collected by A. Veidenberg. The main objective of this study was to identify from 1981 crosses selections which are easy to propagate and to evaluate their suitability for rootstock breeding.

Materials and methods

Rootstock breeding work was carried out in Polli. In 1981 Veidenberg used E53 and E75 as female parents and crossed them in 9 combinations and 4 parallel crosses with E20, E28, E39, E53, E75 and MM106. Also some seeds were collected from open pollinated E53, E75 and MM106. Seeds from crosses were harvested and stratified in winter. In spring 1982 hybrid seeds were sown. During the next growing season the soil was periodically mounded around the shoots, finally resulting in a 15-20 cm mound and in autumn, the soil was removed and the rooted shoots were cut off.

The amount of roots was evaluated in two-year-old seedlings according to a scale: 0 = no roots or only some rootlets, 5 = 5-10 cm of trunk is covered with fascicles. With selected seedlings a propagation trial by mound layerage was established in 1984. During 8 years in stoolbeds the following properties of rootstocks were studied: output of shoots per mother plant, the degree of rooting, producing of spines or branches in 4-point scale (0 = no spines; 4 = four or more spines or branches on layer). The results were expressed as mean ± standard deviation and were analysed statistically with ANOVA.

Results and discussion

From 4747 seeds that were sown, 2686 (56.6%) took root, resulting in a total of 2219 seedlings (46%). Seeds that germinated better were from crosses E53 × E39, E53 × E75 and E75 × E53 (Table 1). In crossing combination E75 × E39 only 31% of seeds were germinated.

One of the most important characteristics of rootstocks in stoolbeds is their ability to form adequate amount of well-rooted shoots. The average rooting of all seedling families was 3.6 (on a scale from 1 to 5), varying from 2.8 to 4.1 (Table 1). However, 232 specimens (10%) stood out with their ability to form additional roots (5 points of 5). The rooting degree of 679 (30.6%) specimens was 4 points, 1028 (46.4%) specimens was 3 points, and rooting of 232 seedlings was only 1-2 points. Better rooting was achieved from following crosses: E53 × E28, E53 × E39, E53 × E75, E53 × MM106 and E75 × E53. For further testing were selected 232 better rooted clones. Selection was successful

on crosses E75 × E53 (43%), E53 × E28 (37%) and E53 × MM106 (30%). During the second evaluation stage the number of genotypes that rooted well decreased, and it constituted 31% of first selection.

During the 8 experimental years the number of genotypes to be evaluated diminished: in 1984 the number of seedlings was 232, in 1986 it was 190, in 1989 it was 160 and in 1992 it was 153. The average output of liners per mother plant was 8,6 during the trial. The better clones (E53 × E75, E75 × MM106) formed accordingly 12.4 and 9.0 layers per mother bush (Table 2). Rootstock propagation by stooling depends on agrotechnical techniques but to a large extent on the genetics of rootstock. Clonal rootstocks E53 and E75, that Veidenberg used in his crossings as female parents are hardy, roots tolerate –12 °C (Veidenberg, 1981), they form large quantities of well rooted shoots (Veidenberg, 1988; Univer and Univer, 2004). Male parents used in the crosses form shoots in satisfactory quantities, 5.9-8.2 shoots per mother plant. In all cross combinations genotypes could be found that gave over 10 liners per mother plant.

The rooting of shoots was only 2.1 points on the 8-year average. Thus, with aging of selections their rooting ability decreased approximately two times. The better rooted shoots occurred in combinations of E53 × MM106 and E53 × E28 (Table 2). According to this data it can be said that during the apple seedling ontogenesis selections diminished their adventitious root formation intensity. At the first evaluation only these specimens of seedlings were selected for further testing whose rooting ability was evaluated with 5 points, in the second evaluation every third plant had rooting of 5 points and after seven years of planting only 3.4% of seedlings had rooting evaluated by maximum value. Diminished rooting ability due to the aging of mother plant in stoolbed has been observed formerly as well. Russian pomologist V. I. Budagovsky (1978) found that rootstock B9 loses its shoot rooting ability in the course of time.

Formation of spines is undesirable feature of stool-shoots. The spininess of stool bed shoots was averagely 1.1 points during the 8 trial years. Seedling families E53 × MM106 produced fewer spines (Table 2). Crosses of E75 × E20, E75 × E28, E75 × MM106 and E53 × E39 produced relatively more spines on stoolbed shoots.

The mother plant may remain productive for up to 20 or more years. In young mother tree plantation were formed on average 3-4 shoots per mother plant, from the third to the fourth year the number of shoots increased to 6-8, and since the fifth year over 10 shoots formed per mother plant. Table 3 lists data of 15 better selections. The most productive genotypes (over 20 shoots per mother plant) were 81-8-7, 81-4-15, 81-4-17 and 81-12-24. But all these selections produced few rooted shoots (1.6–1.8 points during experiment). 16 of 20 better propagable genotypes derive from rootstock E75. The selection 81-8-7 from E75 × MM106 combination was distinguished by his reproduction ability, resulting in 30.1 shoots per mother plant. The progenies of E75 produced adequate quantities of shoots as well. Data of 8-year study revealed that better specimens of cross E53 × E75 gave 23-28 shoots per mother plant. When taking these data into account we can say that the abundant shoot production is a heritable property. Thus, when using E53 and E75 in rootstock breeding it is possible to get genotypes which produce two times more shoots in stool bed than their progenitors.

It was found that seedlings tended to produce the highest number of shoots on

the stool bed in the period of 5-8 years after planting, whereas the root formation was greatest on young shoots. Veidenberg summarized his 12 year study with words: "Unfortunately, there were no selections of 1981 crosses which produce large amounts of well rooted shoots in stoolbed" (Veidenberg, 1992).

Conclusions

1. The apple clone rootstock seedlings go through a juvenile period of 4 years, and after that formation of shoots stabilises on mother plants.
2. The rootstocks E53 and E75 bred at Polli turn out to be good genitors for breeding winter hardy and productive mother plants.
3. From a total of 2219 seedlings resulting from crosses of 1981 there were no hybrids which combine in one genotype adequate amount of shoot formation and good rooting ability of shoots.
4. In one way or another, all E type rootstocks were crosses of 'Anoka' or 'Chulanovka', and it is possible that 1981 crossing series got their poor adventitious roots formation from these cultivars.

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Table 1. Selection of apple seedlings from crosses in 1983

Crosses	Number of seeds	Number of seedlings		Rooting, points	Selected seedlings	
		No	%		No	%
E53 × E28	98	49	50	4.1	18	37
E53 × E39	40	30	75	4.0	8	27
E53 × E75	105	72	69	4.0	19	26
E53 × MM106	60	27	45	4.0	8	30
E53 open pollinated	157	106	68	3.0	17	16
E75 × E20	645	320	50	3.4	25	8
E75 × E28	902	476	53	3.6	32	7
E75 × E39	723	227	31	3.5	34	15
E75 × E53	41	23	56	4.0	10	43
E75 × MM106	1080	377	35	3.5	31	8
E75 open pollinated	604	328	54	2.8	7	1
MM106 open pollinated	292	184	63	3.2	23	12
Total	**4747**	**2219**	**X**	**X**	**232**	**X**
Average	**X**	**X**	**54**	**3.6**	**X**	**19**

Table 2. Propagation by layers of selected apple seedlings in 1985-1992

Crosses	Number of layers			Rooting, points			Spines, points
	average	min	max	average	min	max	
E53 × E28	8.3	4±2	12±3	2.5	1.8±0.1	3.3±0.4	0.9
E53 × E39	7.4	4±1	11±3	1.9	1.6±0.1	2.2±0.4	1.3
E53 × E75	12.4	6±2	23±5	2.0	1.6±0.1	2.8±0.3	1.2
E53 × MM106	8.7	5±1	14±4	2.6	3.1±0.2	2.8±0.4	0.3
E53 open pollinated	8.7	3±1	16±4	2.2	1.6±0.2	2.9±0.4	1.2
E75 × E20	8.7	4±1	15±4	2.2	1.7±0.1	2.9±0.4	1.6
E75 × E28	83	2±1	18±5	2.2	1.6±0.2	2.6±0.4	1.0
E75 × E39	8.9	3±1	12±2	1.9	1.5±0.2	2.4±0.2	1.3
E75 × E53	8.5	6±2	12±3	2.0	1.7±0.2	2.5±0.3	0.9
E75 × MM106	9.0	3±1	30±10	2.1	1.6±0.1	2.9±0.4	1.3
E75 open pollinated	8.5	4±1	13±4	2.0	1.4±0.1	2.6±0.2	0.9
MM106 open pollinated	6.2	2±1	15±4	2.2	1.6±0.1	2.8±0.2	0.9
LSD (5%)	**1.8**	**X**	**X**	**0.3**	**X**	**X**	**0.3**

Table 3. The number of shoots and root formation of better selections in 1985-1992

Selection	Parentage	No. of layers per mother bush									Rooting, points
		1985	1986	1987	1988	1989	1990	1991	1992	average	
81-2-3	E53×E28	4	10	18	8	29	32	11	10	15.3±3.6	1.8±0.3
81-1-6		3	5	8	5	19	25	9	24	12.3±3.2	1.9±0.3
81-4-15	E53×E75	5	7	25	21	49	72	18	31	28.5±7.9	1.6±0.1
81-4-17		7	13	20	14	43	48	20	20	23.1±5.2	1.7±0.2
81-5-6	E53×MM106	5	5	14	2	18	40	10	17	13.9±4.3	2.1±0.2
81-7-11	E53×?	4	6	8	11	28	39	16	20	16.5±4.3	2.0±0.2
81-12-24	E75×E20	4	12	18	8	35	42	11	30	20.0±4.9	1.7±0.2
81-12-7		3	12	7	10	22	32	10	28	15.5±3.7	2.2±0.1
81-12-11		3	3	4	4	23	36	15	25	14.1±4.5	2.1±0.3
81-12-2		5	6	5	8	18	23	16	28	13.6±3.2	1.9±0.1
81-12-22		6	5	5	7	19	32	9	25	13.5±3.7	2.2±0.1
81-15-2	E75×E28	4	6	9	12	26	41	15	30	17.9±4.6	1.9±0.1
81-9-1		3	6	11	8	21	30	10	22	13.9±3.3	1.9±0.1
81-8-7	E75×MM106	4	8	20	10	42	74	14	69	30.1±9.9	1.8±0.2
81-17-5	MM106×?	3	6	11	6	19	33	16	29	15.4±3.9	1.9±0.1

Part B

"RESEARCH OF FRUIT CROP GENETIC RESOURCES FOR USE IN PRODUCTION AND BREEDING. PLANT PHYSIOLOGY AND IN VITRO RESEARCH"

MICROPROPAGATION OF HIGHBUSH BLUEBERRY (*VACCINIUM CORYMBOSUM)*

Maria GEORGIEVA [1], Violeta KONDAKOVA [2]

[1] Research Institute of Mountain Stockbreeding and Agriculture,
281, Vasil Levski str., 5600 Trojan, Bulgaria
e-mail: Maria_Georgieva_bg2000@yahoo.fr
[2] AgroBioInstitute, 8, Dragan Tsankov Blvd., 1164 Sofia, Bulgaria,
e-mail: violeta.kondakova@gmail.com

Abstract

During the last years, the interest and production of highbush blueberry (*Vaccinium corymbosum*) increase a lot, especially in mountain region. It's one of the most significant berries with valuable characteristics and production of secondary metabolites as anthocyanin, which provide human health benefits. One of the limited factors for development and productions is the environmental conditions. Highbush blueberry grows best and most commonly in moist or wet peat of moderate and high acidity soils. The utilization of biotechnology approaches for propagation of several berries cultivars ('Bluecrop', 'Duke', 'Toro' and 'Brigitta Blue') were study. The creation of an efficient *in vitro* system for regeneration was on the basal WPM medium. The effect of zeatin was compared with that of 2-iP in establishment and proliferation phases of leave and stem segments. Rooting of micropropagated plants and genotype relation were also studied. The best regeneration capacity of leave segments from cv. 'Brigitta Blue' (92.2%) was appear on WPM medium supplemented with zeatin – 4.10^{-6} mg.l^{-1} and 2-iP – 5.10^{-6} mg.l^{-1}. The rooting under *in vitro* conditions was in 81.8% on ½ WPM medium supplemented with 10^{-6} mg.l^{-1} IAA for cv. 'Brigitta Blue'.

Key words: blueberry, micropropagation, regeneration, *Vaccinium corymbosum,* zeatin

Introduction

The highbush blueberry (*Vaccinium corymbosum)* belongs to the genus *Vaccinium* (*Ericaceae*) and is widely cultivated in different regions on the world.

The best climate conditions for grow of highbush blueberry cultivars are in United States, Europe, Australia and New Zealand. They are commercially and biologically important small fruits with high content of vitamins, bioactive organic substances with antibacterial and anticancer effects, anthocyanin pigments and also as an excellent source of antioxidants (Wolf et al., 1983; Eccher et al., 2004; Ostrolucka et al., 2007; Meiner et al., 2007).

In Bulgaria there is an increase of interest to establish of production plantations with this species in suitable mountain regions. The traditional way for propagation of high bush blueberry by cuttings is not very efficient and for this reasons we started to investigate regeneration capacity of this species under in vitro conditions.

The development of efficient system for *in vitro* propagation, rooting and adaptation in soil is an essential prerequisite for future distribution of this very valuable fruit.

Material and Methods

In vitro regeneration. All *in vitro* experiments for establish a good protocol for regeneration and rooting of highbush blueberry were carried out with cultivars – 'Bluecrop', 'Duke', 'Toro' and 'Brigitta Blue' coming from Bulgarian-Germany project "Famad". The accessions of these cultivars were stored under greenhouse conditions in separated plots with sterile soil.

For regeneration capacity study we applied two types of explants – leaf portions and stems with length 1 cm separated from middle part of *in vivo* and *in vitro* maintain plants.

Two variants of nutrient medium were studied. The first experiments were carried out on a MS basal nutrient medium supplemented with different growth regulators (Table 1). A part of the explants on these media were put under low-temperature stress (4 °C) for 24 hours. The second experiment was conducted on a WPM basal medium supplemented with 4.10^{-6} mg·l^{-1} zeatin and 5.10^{-6} mg·l^{-1} – 2-iP, (Kondakova et al., 2004) a part being grown under a normal light regime and the rest of them were cultivated in the dark for 14 days.

For the evaluation of regeneration answer two indexes were included and calculated – % of regenerated explants and average number of regenerates on explants.

In vitro rooting. The experiments for *in vitro* rooting of highbush blueberry cultivars were carried out by testing of 15 variants of cultural media supplemented with different growth regulators and ½ WPM basal medium (Table 2). In rooting experiments only cv. 'Brigitta Blue' was tested. The shoots were put separately in tubs with 10 ml medium.

The evaluation of rooting answer was managed after calculating the next index – % of rooting explants, average number of roots per explant and average length of roots.

The cultures were maintained under the same conditions as regenerated explants.

For each experiment 15 explants were used in three replications.

Adaptation. All trials for rooting of *in vitro* shoots were carried out in the same conditions as *in vitro* cultures. The soil included composition of sterile peat + sand (1:1) and high air humidity was maintained. During the time for adaptation air humidity was decreased step-by-step. Generally, there are no problems with adaptation of highbush blueberry cv. 'Brigitta Blue' – we received a very high percent – 92.5% of adaptation.

The processing of all data was made by variation-statistic method (Lidanski, 1988).

Results and Discussion

In vitro regeneration. The main factors influencing on regeneration capacity of highbush blueberry are the kind of explants, genotype and growth conditions. Our experience show that separated leaf explants from *in vivo* plants didn't regenerate on MS basal medium (Murashige and Skoog, 1962). The low temperature treatment of leaf explants for overnight had no with positive effect on morphogenetic regeneration ability.

A comparative study of two basal mediums demonstrated high potential of leaf and stem segments as sources for regeneration. They are separated from *in vitro* plants of all cultivars (cv. 'Bluecrop', cv. 'Duke', cv. 'Toro' and cv. 'Brigitta Blue') growing on WPM basal medium (McCown et al., 1981).

There are reports from many researchers for positive influence of WPM medium on blueberry organogenesis (Zimmerman et al., 1980; Callow et al., 1988; Reed et al., 1991). The explanation of this reaction is the connection of lower quantity of nitrogen and potassium needed for blueberry growing.

Usually two active cytokinines are utilized for adventives organogenesis – zeatin and 2-iP and many researchers confirm zeatin as the more active cytokinine (Debnath, 2001; 2004; Ostroluckà et al., 2004; Gajdo ová et al., 2006; Meiners et al., 2007). Cao et al. (2002) reported for 98% regeneration activity of leaf explants separated from cv. 'Bluecrop' cultivated on medium enriched with TDZ, zeatin and NAA.

Our results show that stem segments are more suitable explants for blueberry regeneration depending of cultivars. For example, the regeneration percentage is quite high – 90.7% for cv. 'Brigitta Blue', 70% for cv. 'Bluecrop', 63.6 for cv. 'Duke' and 57.1% for cv. 'Toro'. The regeneration was calculated after reaction of explants on A' medium, 44 days after cultivation (Table 3). Exception to this dependence is the reaction of leaf explants after dark pre-treatment for 14 days of cv. 'Brigitta Blue'. There was observed high percent of regeneration – 92.2% (Table 4).

Explant response after pre-treatment of *in vitro* growing of shoots from highbush blueberry (*Vaccinium corymbosum)* to different light conditions is a very positive step for increasing of regeneration capacity.

In vitro rooting. The results of *in vitro* rooting ability was strongly related with cultural medium composition ($p < 0.01$) (Figure 1).

Generally, we observed the best rooting on medium R_5, R_6, R_8 and R_9 on ½ WPM basal medium supplemented with two types of auxin – IAA or NAA in concentration 5.10^{-7} mg·l^{-1} – 10^{-6} mg·l^{-1}.

The variants R_{10}-R_{15} with addition of organic compounds meso-inositol and casein hidrolysate were without positive influence on rooting process, but in those that had successfully taken roots, they stimulated the formation of new roots and their growth. Rooting induction was observed on all variants of medium and it is very clear that this species needed auxin. This is proof that blueberry is poor of endogenous hormones and the choice of suitable medium combination is very important.

Comparative evaluation of two kinds of auxin – IAA and NAA showed dependence from its concentration. For example, 10^{-6} mg·l^{-1} IAA gave better regeneration than NAA in the same concentration and opposite – 5.10^{-7} mg·l^{-1} NAA was more effective than 10^{-6} mg·l^{-1} IAA.

The use of IBA (5.10^{-7} mg·l^{-1}) confirmed the positive effect of low concentrations of auxins, which correlated with the results obtained by Wolf et al., 1983; Jaakova et al., 2001; Gajdosova et al. 2006).

The low concentration of auxin (2.10^{-7} mg·l^{-1} – $5{\cdot}10^{-7}$ mg·l^{-1}) was enough for beginning of rhizogenesis and formed a good root system (Figure 2). The results showed highest average number of roots on R_7 medium (3.3 cm) following of variant R_4 (3.2 cm) and R_8 (3.1 cm). The count of root length was the best on R_{10} (1.25 cm) and R_{13} (1.04 cm) ($p < 0.05$) (Figure 2).

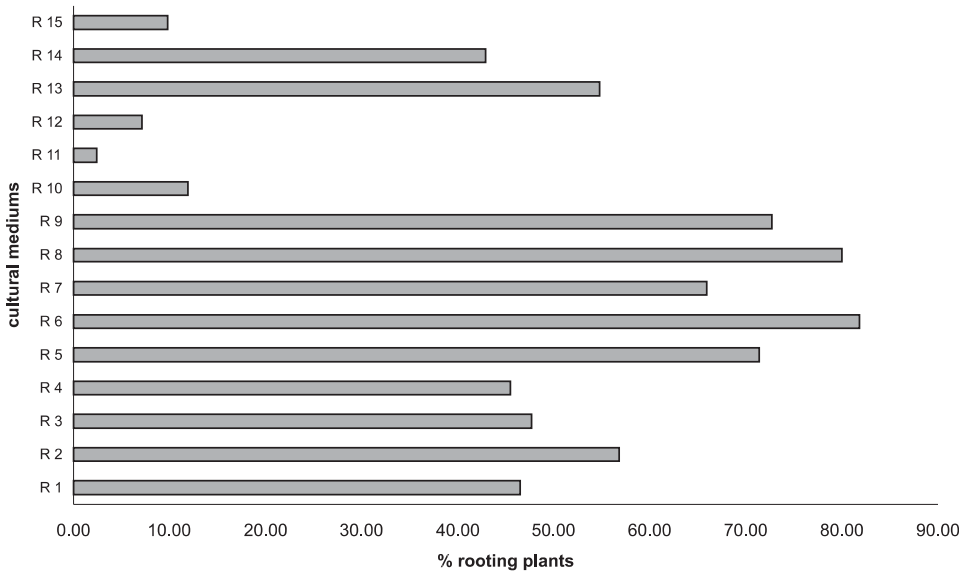

Figure 1. The rooting percentage of highbush blueberry on different culture mediums

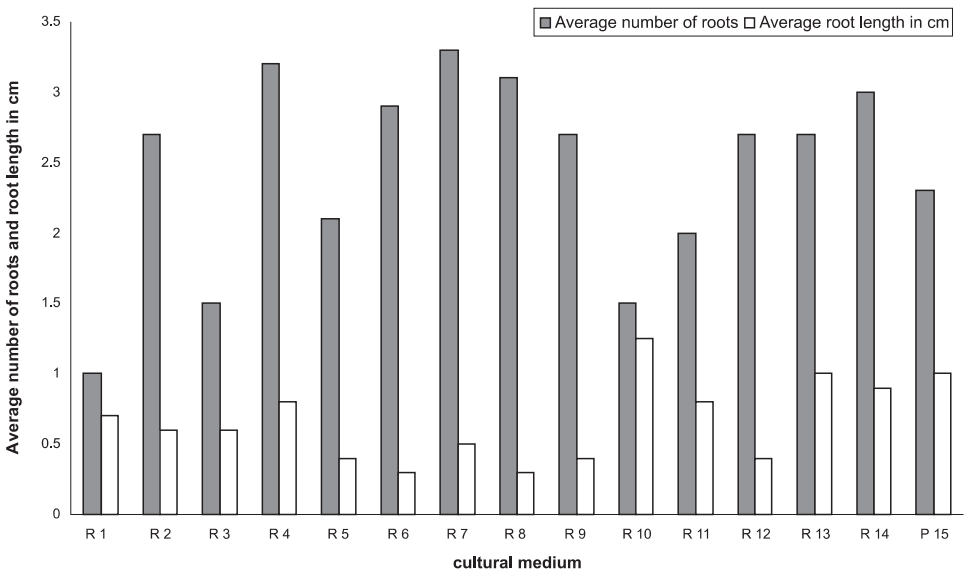

Figure 2. Average number of roots per plant and root length in cm

Conclusions

1. The best regeneration answer of highbush blueberry was given by stem explants isolated from *in vitro* shoots.
2. The most suitable medium for regeneration is based on WPM supplemented with 4.10^{-6} mg·l^{-1} mg/l zeatin and 5.10^{-6} mg·l^{-1} 2-iP.

3. The average number of shoots per explant strongly depends on genotype.
4. The best rhizogenesis was calculated on medium supplemented with auxin 5.10^{-7} mg·l^{-1} NAA or 10^{-6} mg·l^{-1} IAA.
5. The addition of organic compounds – meso-inositol and casein hidrolysate did not influence substantially the rhizogenesis of the micropropagated blueberries, but in those that had successfully taken roots, they stimulated the formation of new roots and their growth.

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Table 1. Composition of regeneration mediums

Medium code	IBA mg/l	BAP mg/l	TDZ mg/l	2-iP mg/l	zeatin mg/l
A	0,5	—	2	—	—
B	0,01	0,5	—	—	—
C (Turk et al., 1994)	0,1	—	0,22	—	—
D (Billing et al., 1988)	—	—	—	3	—
E-2 (Donnelly et al., 1980)	0,1	2	—	—	—
A '	—	—	—	5	4

Table 2. Composition of rooting mediums

Medium code	IBA mg/l	IAA mg/l	NAA mg/l	MI mg/l	CH mg/l
R_1	0.2	—	—	—	—
R_2	0.5	—	—	—	—
R_3	1	—	—	—	—
R_4	—	0.2	—	—	—
R_5	—	0.5	—	—	—
R_6	—	1	—	—	—
R_7	—	—	0.2	—	—
R_8	—	—	0.5	—	—
R_9	—	—	1	—	—
R_{10}	—	—	—	250	250
R_{11}	—	—	—	500	500
R_{12}	—	1	—	250	—
R_{13}	—	1	—	—	250
R_{14}	—	1		500	—
R_{15}	—	1	—	—	500

Table 3. Regeneration of blueberry leaf and stem segments cultivated on medium A'

Cultivars	Explants	Number of explants	Number of regenerated explants	% regeneration	Average number of shoots per explants
Bluecrop	Leaf	15	0	0	0
Bluecrop	Stem	30	21	70	1.6
Duke	Leaf	14	0	0	0
Duke	Stem.	11	7	63.6	1.4
Toro	Leaf	15	0	0	0
Toro	Stem	7	4	57.1	1
Brigitta Blue	Leaf	19	2	59.3	4
Brigitta Blue	Stem	24	22	90.7	10.7

Table 4 . Regeneration of blueberry leaf explants after dark pre-treatment

Cultivars	Explants	Regeneration %	The number of regenerant's from leaf / week						Number of shoots per explants	General number of explants
			1	2	3	4	5	6		
Brigitta Blue **	leaf	92.2	77	81	80	83	83	83	3.20	260
Brigitta Blue **	stem	67.1	49	48	56	55	52	53	1.36	63
Brigitta Blue *	leaf	59.3	93	93	94	95	95	95	2.53	230
Brigitta Blue *	stem	90.7	59	60	70	70	73	74	1.48	96

* Light conditions
** Dark conditions

Table 5. Average number and length of root induction on different hormonal mediums

Medium code	Average number of roots	Average count of root length
	M ± m	M ± m
R_1	1 ± 0	0.67 ± 0.17
R_2	2.67 ± 1.67	0.63 ± 0.23
R_3	1.5 ± 0.23	0.55 ± 0.10
R_4	3.18 ± 0.45	0.78 ± 0.04
R_5	2.12 ± 0.38	0.42 ± 0.08
R_6	2.89 ± 0.17	0.25 ± 0.04
R_7	3.33 ± 0.84	0.46 ± 0.08
R_8	3.07 ± 0.20	0.34 ± 0.02
R_9	2.73 ± 0.58	0.36 ± 0.08
R_{10}	1.5 ± 0.24	1.25 ± 0.21
R_{11}	0	0
R_{12}	2.67 ± 1.20	0.4 ± 0.15
R_{13}	2.7 ± 0.32	1.04 ± 0.14
R_{14}	3 ± 0.40	0.87 ± 0.18
R_{15}	2.25 ± 0.33	0.98 ± 0.35
$LSD_{0.05}$	2.9	1.0

ADAPTATION OF FOREIGN PLUM AND CHERRY VARIETIES IN SWEDEN

Inger HJALMARSSON[1], Viktor TRAJKOVSKI[2], Björn WALLACE[3]

[1]Swedish Biodiversity Centre, PO Box 54, S-230 53 Alnarp
e-mail: inger.hjalmarsson@cbm.slu.se
[2]Swedish Pomological Science Centre, Stubbaröd 2818, S-260 23 Kågeröd, Sweden
e-mail: viktor.trajkovski@telia.com
[3]Stockholm School of Economics, P.O. Box 6501, S-113 83 Stockholm, Sweden
e-mail: bjorn.wallace@hhs.se

Abstract

Fruit growing has a long tradition in Sweden with indigenous Nordic as well as foreign varieties frequently being grown in private gardens and commercial orchards. In this article we analyse the geographical origins of varieties with focus on stone fruits. The assortment of plums and cherries in the most influential Swedish pomologies was investigated along with that of the national fruit gene bank mandate variety list. Furthermore, we discuss how fruit genetic resources from other countries with different climates have influenced the Swedish pomological heritage. In total we found 116 plum varieties, whereof 23 % were Swedish, 59 % foreign and 17 % of uncertain origin. Seventeen percent of the foreign varieties were non-European, and these all were North American. As for cherries, a total of 96 varieties were identified. Among these 18 % originated from Sweden, 73 % from abroad and 9 % were of uncertain origin. Fourteen percent of the foreign varieties were non-European, and again all of these were North American. The main donor countries for both plums and cherries were England, France and Germany, i.e. countries characterized by warmer climate than Sweden. Thus, we can also conclude that certain plum and cherry genetic resources from southern latitudes may adapt well to the relatively harsh Swedish climate.

Key words: *Prunus domestica* L., *Prunus avium* L., *Prunus cerasus* L., pomology, cultivar, climate adaptation

Introduction

The progenitors of the cultivated European plum (*Prunus domestica* L.), sweet cherry (*Prunus avium* L.) and sour cherry (*Prunus cerasus* L.) probably originated from Central Asia, where many fruit species have their centres of diversity. Sweet cherry with the chromosome number 2n = 16 is considered more ancient than plum (2n = 48) and sour cherry (2 n = 32). It has been suggested that the European plum arose through a hybridization between cherry plum *P. cerasifera* (2n = 16) and sloe *P. spinosa* (2n = 32) followed by a spontaneous doubling of the resulting sterile triploid (Westwood, 1993). Small fruited bullace plums, *P. domestica ssp. insititia* (L) Poir, have the same origin as the European plum and may cross with this species as well as with sloe. The mixed ancestry of the European plum has created a large variation in fruit characteristics, i.e. size, shape, colour, and taste. As for sour cherry evidence suggest that it arose from a cross between an unreduced sweet cherry pollen grain and *P. fruticosa* (2n = 32) (Westwood, 1993). Since ancient times, sweet cherry is considered naturalised in most of Europe. Probably it was carried west- and northward by birds. Thus, sweet cherry,

and likewise sloe, is also naturalised in the warmer regions of Scandinavia. Findings in Norwegian graves indicate that sweet cherries picked from natural stands were a part of the diet in Sognefjord already 1500 years ago (Schübeler, 1888). Furthermore, in his "History of Northern People" Olaus Magnus (2001 [1555]) gives a detailed description of the abundance of wild cherry trees on the slopes of Kinnekulle, a table mountain in the county of Västergötland (central Sweden).

In Sweden stone fruits were first cultivated during the Middle Ages, when monks brought plants of bullace plums and cherries to their monastic gardens (Hjelmqvist, 1991). During the 17th and 18th century fruit growing became popular among the Swedish nobility, which imported plum and cherry trees from nurseries in southern Europe. Both named cultivars and seedlings were thus brought to the country. However, the imported quantities were less than for apple and pears at the same time. Some of the imports survived and remained in Swedish orchards. Other varieties and tree individuals could not withstand the Scandinavian climate and were sorted out. The first attempt to systematically describe and classify the fruit varieties grown in Sweden was made by Eneroth, who published his pomology in 1866. This was followed by a revised edition at the turn of the century (Eneroth and Smirnoff, 1896-1901). The next Swedish pomology to be written was authored by Dahl, who only included apples and pears in his first edition, but added plums to the second edition in 1943. Though it was never published Dahl also prepared a separate cherry pomology, a manuscript which was subsequently included in Fernqvist (1988). In the 1980s a new Swedish pomology was published by Nilsson, who included plums and cherries in his second volume (1989). By this time the main focus was on genuine Swedish varieties, rather than on imported ones. Since 2003 the interest for old plant material is manifested through the national program for cultivated plants (Programmet för Odlad Mångfald – POM). Today's conservation efforts include Swedish mandate varieties, i.e. varieties of Swedish origin which either have been named and spread locally, or bred and marketed by Swedish plant breeders (Hjalmarsson, 2003). Foreign varieties for which a longstanding growing tradition in Sweden can be documented are also included.

The aim of this paper is to carry out analyses of the assortment of plums and cherries in the Swedish pomological literature and in the Swedish mandate variety list. It documents and highlights the substantial influence of foreign plum and cherry genetic resources in Swedish horticulture.

Materials and methods

For our study the following editions of Swedish pomologies were selected: Eneroth (1866) (plums and cherries), Eneroth and Smirnoff (1901) (plums and cherries), Dahl (1943) (plums), Fernqvist (1988) (cherries), and Nilsson (1989) (plums and cherries). Fernqvist (1988) comprised 55 variety descriptions, whereof 18 were written by Dahl in the early 1940s. All varieties in the studied material were arranged in two tables, one for plums, and one for cherries. Furthermore, each variety was checked for synonyms and its country of origin was noted. The complete material includes 116, to our knowledge, unique plum and 96 cherry varieties.

Results

Plums. In total 116 plum varieties were identified (Table 1). On average each variety appeared in the study twice. Of the 116 registered varieties 23 % were indigenous, 59 % originated from other countries and 17 % had uncertain origin. Seventeen percent of the foreign varieties were non-European, and all of these were North American. Among European donor countries England, France and Germany were the most important contributing with 16, 14 and 14 varieties respectively, i.e. 64 % of the total foreign material.

Following the time axis represented by the pomologies it can be seen that the total number of listed varieties was 47 in 1866. This figure increased to 65 in 1901, and then declined, so that the number of varieties in Nilsson (1989) was actually six fewer than in Eneroth (1866). For varieties with uncertain origins a decline is noted from 32 % of the total number in 1866 to 12 % in 1989. During the same period the Swedish influence grew stronger and the percentage of national varieties increased from 15 to 34. However, a decline was noted in 1943 when indigenous varieties only amounted to 7 %. Among European donor countries Bohemia has been classified separately. All the Bohemian varieties emanated from the pomologist G. Liegel (1777-1837), who introduced and spread several plum cultivars. The share of North American varieties fluctuated around 10 % throughout the period of study, and only in the mandate list is this figure lower (3 %). Compared to the pomologies the assortment in the mandate list is clearly biased towards Swedish varieties.

Cherries. The study comprised 96 cherry varieties. As can be seen from Table 2 each variety appeared approximately twice in the studied material. Of the 96 varieties 18 % were indigenous, 73% originated from other countries and 9 % had uncertain origin. Fourteen percent of the foreign varieties were non-European, and as for plums all of these were North American. Among European donor countries Germany, England and France were the most important contributing with 26, 13 and 9 varieties respectively, i.e. 55 % of the total foreign material.

Following the time axis represented by the pomologies it can be noted that the number of varieties in the oldest pomology (Eneroth, 1866) and the most recent (Nilsson, 1989) is about the same, approximately 30. Fernqvist (1988) includes descriptions from two decades, and describes 55 varieties. The number of varieties with uncertain origin was substantially higher in 1866 and 1901 (24 %) than in the 1988 (4 %) and 1989 (10 %). Notably the number of varieties with Swedish background was below 6 % in 1866, 1901 and 1988, i.e. less than half of the 17 % in Nilsson (1989). Non-European varieties are only found in the most recent pomologies. Twenty-four percent of the varieties included in Fernqvist (1988) are from North America, and all of these were described in the 1980s. In Nilsson (1989) the American influence is limited to 3 %. Also for cherries, the mandate list is biased towards Swedish varieties.

Discussion

Plums. In the pomological literature varieties tend to be described with their history. Our geographical classifications were based on this information. Plums classified as indigenous fall in two main categories, either local plums of bullace type, or modern

varieties from Swedish breeding programs. The earliest plum varieties were probably brought to Sweden during the Middle Ages as seeds or plants (Hjelmqvist, 1991). It is also possible that some of them arose from natural hybrids between the imported material and the native sloe. Most local plum varieties produce large quantities of small fruits and are very hardy. Another advantage is that they may produce suckers. Thus, the most traditional way of plum cultivation in Sweden was through local varieties on their own roots. In our study 12 local varieties were identified. Of these, the yellow fruited 'Allmänt gulplommon' and the green fruited 'Hackman' appeared in all four pomologies. The former was considered Sweden's most common variety in the middle of the 19th century (Eneroth, 1866). Similar types of plums are also reported from Norway and the Baltic countries (Dahl, 1943). 'Hackman' was first mentioned in a nursery catalogue from Löberöd estate (south Sweden) in 1837, and remained popular in Scandinavian gardens for almost a century. 'Mälarplommon' with white yellowish fruits was frequently grown in the Stockholm archipelago, and sold in large quantities on the markets in the capital. In the 1920s it was still the most common commercial variety in this region (von Post, 1927). Along with the yellow and green fruited local cultivars there are also red fruited bullace plums and blue fruited prunes.

In spite of the successful commerce with local cultivars, there was a strong interest from the Swedish nobility and horticulturists to introduce foreign large fruited varieties. Import of cultivars for testing began in the middle of the 19th century. Eneroth and Smirnoff (1901) mention that Eneroth 1862-1875 established test orchards at four different estates in southern Sweden. Furthermore, Eneroth and Smirnoff report that 125 cultivars were tested at the Experimental Field of the Royal Swedish Academy of Agriculture in Stockholm, and that 300 cultivars were evaluated at the Institute of Horticulture at Alnarp (south Sweden). The Academy is known for its introduction of Scandinavia's most famous prune 'Experimentalfältets sviskon' (obtained through a seedling from 'Frühe englische Zwetsche'), which was spread in the 1890s. In 1932 the assortment of plums was investigated in 54 Swedish nurseries (Reimer, 1942). The ten most popular were 'Victoria' (England), 'Oullins Gage' (France), 'Czar'(England), 'Jefferson' (USA), 'Green Gage' (France), 'Experimentalfältets sviskon' (Sweden), 'Rivers early Prolific' (England), 'Orleans' (France) and 'Allmänt gulplommon' (Sweden). The foreign influence is clearly seen as in our investigation. All of the above ten varieties are now on the mandate list.

In the 20th century cultivar research was concentrated to Alnarp where testing of imported varieties continued. Our study showed that only 22 of the 40 foreign varieties described by Eneroth and Smirnoff were considered worthwhile growing by Dahl in 1943. The varieties 'Ariel', 'Opal' and 'Emil' were results of breeding activities at Alnarp. Of these 'Opal' ('Oullins Gage' x 'Early Favourite') introduced in 1944 was the most successful. After the Second World War Swedish plum breeding moved to the Fruit Breeding Institute at Balsgård (south Sweden), from where seven varieties were released between 1967 and 1997. Only one of them, 'Madame' ('Hackman' x 'Victoria'), has a Swedish local variety in its pedigree. Compared to apple the assortment of plum is very limited, and there is no increase in the number of varieties following the time axis of the pomologies as can be seen for apples (Hjalmarsson and Trajkovski, 2007). The fact that

plum is less hardy than apple, and that Swedish interest for plum production has always been low may explain the difference between the crops. According to statistics from the Swedish Board of Agriculture only 300 tons of plums were commercially harvested in 2005 (Anonymous, 2006)

Cherries. The development of cherry cultivars in Sweden has been similar to that of plums. Monks probably made the first import of sweet and sour cherry varieties during the Middle Ages (Hjelmqvist, 1991). The interest for cherry cultivation was then passed on to the royalty and nobility. Already during 16th century the Swedish Vasa-kings planted cherry groves at their castles, and in the 17th century extensive cherry cultivation amongst ordinary farmers in the counties of Östergötland and Västergötland were reported (Dahl, 1988). These plantations remained profitable for more than a century as both climate and soil were favourable for cherry production. Also, indigenous sweet cherries occur in these areas, and probably had an impact on the first assortment of cultivated cherry. In contrast sour cherry orchards were exclusively based on imported material, which like bullace plums was easily spread on the countryside thorough plants on their own roots. In our study six foreign cultivars are mentioned in all four pomologies. Three of them, 'Allmän gulröd bigarrå', 'May Duke' (a hybrid between sweet and sour cherry) and 'Brunkörsbär' (sour cherry), were known in Sweden already in the 17th century. The other three, 'Napoleon', 'Stor svart bigarrå' and 'Ostheimer' (sour cherry), were imported by Eneroth in the 1860s. Eneroth performed his cultivar testing at different private estates in southern Sweden. As for plum, evaluation of cultivars was also performed at the Academy in Stockholm. When the Institute of Horticulture at Alnarp started its activities in 1862 the first import of foreign cherry material was obtained from J.G. Oberdick, Jeinsen, Hannover (Dahl, 1988). No less than 80 cherry varieties were marketed from Alnarps nursery in 1880, but already in 1892 the assortment had been reduced to 31. In spite of the high influx of foreign cherry varieties it can be noted that the assortment in Eneroth (1866) and Eneroth and Smirnoff (1901) is limited to approximately 35 varieties.

The turn of 19th and 20th century was critical for Swedish cherry cultivation. Severe attacks by insects and birds caused unexpected losses, and discouraged growers to make further investments. However, some interest remained in Västergötland, where a trial with 55 varieties was planted 1924-25 (Hülpers, 1937). When a governmental research organisation, Statens Trädgårdsföresök, was established in 1938 new foreign varieties were imported for testing at Alnarp, and the experimental station at Rånna, Västergötland. In the 1950s cherry breeding began at Balsgård and as a result 'Almore' ('Napoleon' x 'Frogmore') and 'Heidi' ('Allmän gulröd bigarrå' x 'Büttners Rote Knorpelkirsche') were introduced in 1982 and 1985 respectively. In the 1970s a new breeding program for sour cherry was started. The main aim of this program was to produce dwarfy cultivars suitable for home gardens and intense commercial production. Thus 'Kirsa' and 'Pernilla' were obtained through crosses between 'Brysselska Bruna' and 'Heimann's Rubin'. Both were marketed in 1988 and sold as trees on their own root. A few years later a third compact sour cherry variety, 'Nordia' ('Tschernokorka' x 'BPr 24179') x ('Vladimir O-241' x 'Brysselska Bruna'), was released. All three varieties are hardy, and 'Nordia' is also resistant against *Monilia laxa*.

Eight of 18 varieties described by Dahl in Fernqvist (1988) can also be found in Eneroth and Smirnoff (1901). The newcomers in Fernqvist are mainly sweet cherries belonging to the 'Merton'-series from the John Innes Institute in England, and from different research stations in Canada and US. However, most of these were never really introduced on the Swedish market, and thus only 'Merton Glory', 'Merton Premier' and 'Van' remained in Nilsson (1989). The number of varieties in Fernqvist is relative high (55) compared to the other pomologies where the figure varies from 28 to 37. Thus, the assortment of cherry traditionally grown in Sweden is even more restricted than for plums, which to a large extent can be explained by low commercial interest. According to statistics from the Swedish Board of Agriculture only 140 tons of cherries were commercially harvested in 2005 (Anonymous, 2006)

Conclusions

Our review of the Swedish pomological literature and the mandate list revealed that 116 plum and 96 cherry varieties were considered suitable for Swedish orchards, and that a large fraction of these were imported from abroad. In addition we found that more than 90 % of the Swedish bred cultivars originate from crosses with foreign varieties. In spite of a strong focus on the national heritage in the most recent pomology (Nilsson, 1989) the percentage of imports is as high as 66 % for plums and 83 % for cherries. In the Swedish mandate list, which reflects the national pomological heritage, the corresponding figures are about 45 %. The main donor countries for plum and cherry are England, France and Germany. All of these countries are characterized by warmer climate than Sweden, and thus we can also conclude that certain plum and cherry genetic resources from southern latitudes may adapt well to the relatively harsh Swedish climate.

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Table 1. Plums: Origin of Swedish mandate varieties and varieties appearing in the pomology books of Eneroth (1866), Eneroth and Smirnoff (1901), Dahl (1943) and Nilsson (1986).

Country of origin	No of varieties in Eneroth (1866)	No of varieties in Eneroth and Smirnoff (1901)	No of varieties in Dahl (1943)	No of varieties in Nilsson (1989)	No of mandate varieties	Total no of varieties	Totla number of observations
Sweden	7	8	4	14	22	27	55
Belgium and Netherlands	3	5	6	2	1	7	17
Bohemia	1	5	4	.	.	8	10
England	4	9	11	6	5	16	35
France	5	7	10	7	6	14	35
Germany	7	9	5	3	1	14	25
North America	5	5	8	4	1	10	23
Uncertain	15	17	7	5	4	20	48
Summary	47	65	55	41	40	116	248
% of total	41	56	47	35	34	100	214
% Swedish	15	12	7	34	55	23	
% foreign	53	62	80	54	35	59	
% uncertain	32	26	13	12	10	17	

Table 2. Cherries: Origin of Swedish mandate varieties and varieties appearing in the pomology books of Eneroth (1866), Eneroth and Smirnoff (1901), Fernqvist (1943-1988) and Nilsson (1989)

Country of origin	No of varieties in Eneroth (1866)	No of varieties in Eneroth and Smirnoff (1901)	No of varieties in Fernqvist (1941-1988)	No of varieties in Nilsson (1989)	No of mandate varieties	Total no of varieties	Totla number of observations
Sweden	1	1	3	5	16	17	26
Netherlands	3	3	1	1	1	5	9
England	4	4	11	6	1	13	26
France	4	5	6	4	2	9	21
Germany	12	14	16	8	5	26	55
North America	.	.	13	1	.	13	14
Other foreign countries	1	1	3	1	.	4	6
Uncertain	8	9	2	3	3	9	25
Summary	33	37	55	29	28	96	182
% of total	34	39	57	30	29	100	189
% Swedish	3	3	5	17	57	18	
% foreign	73	73	91	73	32	73	
% uncertain	24	24	4	10	11	9	

WINTER INJURIES OF PLUM CULTIVARS IN WINTERS 2005–2007 IN ESTONIA

Heljo JÄNES and Kersti KAHU

Polli Horticultural Research Centre of the Institute of Agricultural and Environmental Sciences, Estonian University of Life Sciences, Kreutzwaldi St. 1, 51014 Tartu, Estonia;
e-mail: heljo.janes@emu.ee

Abstract

Two subsequent winters, 2005/2006 and 2006/2007 have been destructive for plums in Estonia. The lowest temperatures of 2005/2006 winter in Polli were in late January when minimum air temperature fell to –29.3 °C and snow cover was only 6 cm thick. The next summer was extremely dry, followed by long and warm autumn. The winter 2007 included two cold periods in February with minimum temperatures ranging from –22.2 °C to –27.7 °C. The aim of present study was to test 40 European plum cultivars and selections as well as 10 cherry plum cultivars for winter hardiness after these two cold winters. Freeze injuries were quantified at the whole tree level using the rating scale: 1= no visible injury; 9= plants entirely destroyed. The cultivars exhibiting the least winter injury symptoms were ´Yevrazia 21´, ´Mount Royal´, ´Zarechnaya Rannyaya´, ´Hiiu Sinine´, ´Polli Munaploom´, ´Tulskaya Chernaya´, ´Märjamaa´, ´Polli Viljakas´, ´Iskra´, ´Perdrigon´ and ´Liivi Kollane Munaploom´ (average ratings from 1.5 to 2.6 points). Also the least winter injuries were shown by selections Jorru, Maiu and Volli Ploom (average ratings from 1.5 to 3.6 points). The most damaged were trees of cultivars ´Suur Tõll´, ´Stanley´, ´Reine Claude d´Oullins´, ´Julius´, ´Jubileum´ and ´Kadri´ (average ratings from 7.5 to 8.4 points). From cherry plum hybrid cultivars the most hardy were ´Mara´, ´Skoroplodnaya´ and ´Kubanskaya Kometa´ (average ratings from 2.5 to 4.8 points).

Key words: cherry plum, cultivars, European plum, winter injuries

Introduction

Winters in Estonia are characterized by considerable fluctuations of temperature and sharp changes in weather conditions. During last 12 years the winters of 1995/1996, 1996/1997, 2000/2001 and 2002/2003 were among the coldest, having minimum temperatures from –32.5 to –32.5 °C. Especially cold was winter of 2003. The coldest winter temperature –27.0 °C (at the snow level – 37.6 °C) was recorded in January 11. These winters have caused very serious injuries to Estonian plum orchards (Jänes et al., 2007).

Winter injuries are usually caused by a combination of freezing, drying and other factors, rather than by low temperatures alone. Especially hazardous for plum trees are periods of mild temperature in winter which may cause trees to become susceptible to winter damage in subsequent cold periods (Tyurina et al., 2000). When there are wide fluctuations in temperatures then this can result in frost cracking and "sunscald" on tree trunks and large limbs. Winter damage may be immediately apparent on plants even before the end of winter but some forms of winter damage may not be evident until June or even later.

The flower buds were usually the most severely affected as they are the least tolerant to fluctuating temperatures. The flower bud injuries caused by mid-winter colds is the main type of injury of plums experienced in Estonia (Jänes, 1996). It is evident also

that late spring frosts severely limit plum production in our climate since the flowering period for all cultivars occurred in early to mid May. The aim of present study was to test the resistance of plum cultivars and of perspective selections to low temperature during two subsequent cold winters.

Materials and methods

40 European plum cultivars and selections and 11 cherry plum cultivars grafted on *Prunus cerasifera* Ehrh. seedlings were evaluated for winter hardiness during two winters, 2005/2006 and 2006/2007 at the Polli Horticultural Research Centre. 24 European plum cultivars and selections were of the Estonian origin, another 16 as well as 11 cherry plum hybrid cultivars were introduced from the other countries. Cultivar ´Ave´ was chosen as a control cultivar for the European plums and ´Mara´ for cherry plum hybrid cultivars. Trees were planted in 2000-2002 at a spacing of 5 x 3 m. Each cultivar or selection was presented by six trees, two trees in a plot in three replications.

The soil type was medium sandy clay, with a pH of 6.7 and a content of humus of 1.5%. Soil was mechanically clean cultivated for four years after planting, then grass sward was established between the rows. Herbicide strips were maintained along tree rows and grass sward was mown several times during summer in alleyways. Trees were rated for winter injury in July 2006 and 2007. Tree injury was quantified using the following rating scale: 1 = no visible injury; 3 = one year shoots and flower buds damaged; 5 = two- and three years branches and trunks damaged; 7 = entire above ground part damaged but in a year new shoots arise; 9 = plants destroyed by cold entirely.

The data were elaborated statistically by analysis of variance and differences were compared using LSD test at $P = 0.05$.

Weather conditions. Weather conditions in 2005/2006 and 2006/2007 were fixed according to the data of Polli weather station. The winter of 2005/2006 was cold. The December was rather mild with the minimum air temperature –16 °C. Period from January 18 till January 23 was very cold with the lowest air temperature -29.3 °C, and snow cover was only 6 cm thick. In end of February and in March there were wide fluctuations of temperatures. The spring frosts –3.4 °C appeared in middle of May. The summer of 2006 was extremely dry (sum of precipitation from May to August was only 119 mm), followed by long and warm autumn. The following winter 2006/2007 included two cold periods in February with minimum temperatures ranging from –22.2 °C to –27.7° C. In addition, spring frost of -2.5° C appeared on May 13, 2007.

Results

According to our results all the 40 European plum cultivars and selections tested could be classified into five groups (the most winter hardy, relatively winter hardy, intermediate hardy, relatively winter susceptible and the most winter susceptible). It was observed that only minimal injury of trees (from 1.5 to 2.6 points) showed trees of eight cultivars: ´Yevrazia 21´, ´Mount Royal´, ´Zarechnaya Rannyaya´, ´Hiiu Sinine´, ´Tulskaya Chernaya´, ´Polli Munaploom´, ´Märjamaa´ and ´Polli Viljakas´, and two selections (Jorru and Maiu) (Table 1). Flower buds of them began to flower in springs of 2006 and 2007, but were seriously injured because of late spring frosts in May. Flower

buds of all other cultivars were totally killed and no flowering was occurred in 2006 or in 2007 springs. Trees of three cultivars: ´Iskra´, ´Perdrigon´ and ´Liivi Kollane Munaploom´, and a selection Volli Ploom could be classified as relatively winter hardy (average injury ratings from 3.4 to 4.0 points). Trees of five cultivars: ´Smolinka´, ´Pärnu Sinine´, ´Kihelkonna´, ´Emma Leppermann´ and ´Renklod Yenikeyeva´, as well as of five selections Mari, Olympia, Polli Varane, Villu and Polli Emma showed intermediate hardiness (from 4.7 to 5.3 points). Six cultivars: ´Suur Tõll´, ´Stanley´, ´Reine Claude d´Oullins´, ´Julius´, ´Jubileum´ and ´Kadri´ were classified as the most winter susceptible (average ratings from 7.5 to 8.4 points) and almost all of their trees were totally killed. Nine cultivars: ´Norgen´, ´Queen Victoria´, ´Liisu´, ´Renklod Haritonovoi´, ´Noarootsi Punane´, ´Ave´, ´Vilmitar´, ´Vilnor´ and ´Duke of Edinburgh´ as well as selection Reetta were classified as winter susceptible (average ratings from 5.7 to 6.8 points) but were mostly recovered in a year from new shoots.

Cherry plum hybrid cultivars showed injuries from 2.5 to 7.3 points. The most winter hardy were ´Mara´, ´Skoroplodnaya´ and ´Kubanskaya Kometa´ (average ratings from 2.5 to 4.8 points). The most injured were ´Chelyabinskaya´ (7.3 points), ´Inese´ and ´Naidena´ (both 7.2 points). Trees of these three cultivars were totally killed.

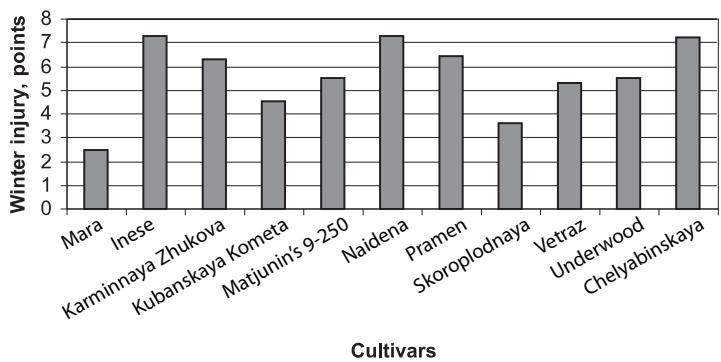

Figure 1. Winter injuries of cherry plum hybrid cultivars on average two years.
$LSD_{0.05}$ = 0.3 for cultivars; $LSD_{0.05}$ = 1.9 for years; $LSD_{0.05}$ = 1.1 for cultivars x years.

Discussion

Cold winters and spring frosts are the main problem in plum production in Estonia. ´Mount Royal´, a new cultivar in Estonia showed very good winter hardiness, and is apparently well adapted to our conditions. The high winter hardiness of ´Mount Royal´ was reported also in USA (Domoto, 1994) and in Byelorussia (Matveyev et al., 2007).

The Russian origin cultivars ´Tulskaya Chernaya´, ´Yevrazia 21´ and ´Zarechnaya Rannyaya´ have already many years exhibited the best winter hardiness in Estonian conditions (Jänes, Pae, 2001; Jänes et al., 2005). The same cultivars have shown the best winter hardiness in Russian trials (Yevstratov et al., 2000).

The previous results permit to state that cultivars ´Hiiu Sinine´, ´Märjamaa´, Polli Munaploom´ and ´Polli Viljakas´ had been the most resistant in many cold winters (Jaama, Jaama, 1990; Jänes, 1996). It is rather notable and positive that trees of our

two selections, Jorru and Maiu exhibited such good winter hardiness in the present study. These selections have not been investigated for winter hardiness before. But, unexpectedly, trees of ´Noarootsi Punane´ have been very badly injured during the winters of 2005/2006 and 2006/2007. This observation is rather surprising as it is not in agreement with our previous findings where this cultivar was classified as the hardiest in Estonia (Jaama, Jaama, 1990). Duchovskis et al., (2007) reported that one of the factors of plum cold resistance is the possibility to be hardened gradually in autumn and at the beginning of winter, at temperatures from –5 to –10 °C. So it might be that the very long and warm autumn (average air temperatures in October, November and December of 2006 were 8.1, 2.5 and 3.2 °C, respectively) has hindered plum cultivars to perform normal preparations for wintering. It could be also that long lasted drought during the growth period and the high temperatures in summer predisposed trees to cold injury.

That ´Kadri´ was classified as very susceptible during these two winters it was not surprise to us, since the trees of this cultivar had often showed bad overwintering. In Byelorussian trials ´Kadri´ has behaved as a winter hardy cultivar, being hardier than e.g. ´Ave´, ´Renklod Yenikeyeva´ and ´Vilnor´ (Matveyev, et al., 2007).

Among cherry plum hybrid cultivars ´Mara´ has been in years the most winter hardy whereas ´Naidena´, on the contrary, the most susceptible in our conditions (Jänes, Pae, 2002). It is interesting to note that in winters 1993-1997 trees of ´Skoroplodnaya´ have been often seriously injured, but in present study their winter hardiness was rather good. According to the data of Russian trials (Yevstratov et al., 2000), ´Skoroplodnaya´ has proved to be one of the best in winter hardiness.

Conclusions

On the basis of this study the following may be concluded:

1. Plum cultivars and selections varied greatly in winter hardiness;
2. Among European plum cultivars the most winter hardy were: ´Mount Royal´, ´Yevrazia 21´, ´Zarechnaya Rannyaya´, ´Hiiu Sinine´, ´Polli Munaploom´, ´Tulskaya Chernaya´, ´Märjamaa´ and ´Polli Viljakas´;
3. The most winter hardy Estonian selections were Jorru and Maiu;
4. Among cherry plum cultivars the most winter hardy were: ´Mara´, ´Skoroplodnaya´ and ´Kubanskaya Kometa´.

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Table 1. Winter injuries of European plum cultivars and selections on average in two winters.

Winter hardiness	Cultivar or selection	Winter injuries (points)	Averages (points)
The most winter susceptible	Suur Tõll, Stanley, Reine Claude d´Oullins, Julius, Jubileum, Kadri	7.5-8.4	7.9
Winter susceptible	Norgen, Queen Victoria, Liisu, Renklod Haritonovoi, Noarootsi Punane, Ave, Vilmitar, Reetta, Vilnor, Duke of Edinburgh	5.7-6.8	6.3
Intermediate hardy	Polli Varane, Smolinka, Mari, Olympia, Villu, Pärnu Sinine, Kihelkonna, Emma Leppermann, Renklod Yenikeyeva, Polli Emma	4.7-5.3	5.0
Relatively winter hardy	Iskra, Perdrigon, Volli Ploom, Liivi Kollane Munaploom	3.4-4.0	3.6
The most winter hardy	Yevrazia 21, Jorru, Mount Royal, Zarechnaya Rannyaya, Hiiu Sinine, Polli Munaploom, Tulskaya Chernaya, Märjamaa, Maiu, Polli Viljakas	1.5-2.6	2.0
$LSD_{0.05}$ = 0.3 for cultivars x years		1.3	

FRUIT CROP GENETIC RESOURCES IN THE ESTONIAN UNIVERSITY OF LIFE SCIENCES

Ave KIKAS, Kalju KASK, Heljo JÄNES, Toivo UNIVER, Asta LIBEK, Liina ARUS, Krista TIIRMAA, Hedi KALDMÄE

Polli Horticultural Research Centre of the Institute of Agricultural and Environmental Sciences of the Estonian University of Life Sciences
Polli, 69108 Karksi-Nuia, Estonia,
e-mail: polli@emu.ee

Abstract

Collections of fruit crop genetic resources of the Institute of Agricultural and Environmental Sciences of the Estonian University of Life Sciences are situated at the Polli Horticultural Research Centre in South Estonia. In 2007, the total number of the accessions was 936 of 17 tree fruit and small fruit crops, including 330 apple, 97 pear, 81 plum, 62 sweet cherry, 18 sour cherry, 55 strawberry, 5 cranberry, 62 raspberry, 97 black currant, 32 red and white currant, 30 gooseberry, 15 edible honeysuckle, 20 sea-buckthorn, and 17 rowan-tree cultivars. The most important constituent part (127 cultivars) of the collections is the cultivars of Estonia's origin. The database is transferred to the Nordic Gene Bank and includes information of 253 cultivars and selections, bred in Estonia; it is available to every researcher and person being interested in it.

Key words: breeding, database, fruit crops, genetic resources

Introduction

The Estonian National Programme "Collection and Conservation of Plant Genetic Resources for Food and Agriculture" has been formally approved and finances allocated by the Government of Estonia in 2002. The Council of PGRFA organized by the Estonian Ministry of Agriculture coordinates programme. The main task for preservation the genetic resources of fruit and small fruit varieties has been the inventory of cultivars originating in Estonia and laying the foundation of living collections (Jänes et al., 2006). Besides Estonian cultivars the collections includes the foreign cultivars that were introduced for producing fruits, using in breeding programs as parents and for screening the prospective cultivars in both aspects. Polli Horticultural Research Centre is the only institution in Estonia, which is engaged in circumstantial investigation of fruit and small fruit cultivars. The repository has a common mission: to collect, maintain, distribute and evaluate genetic resources. The most important characteristics investigated are: resistance to frost and some economically important diseases, yield potential, blooming time, self-compatibility, ripening time, storage ability, attractiveness of fruits, their flavour and chemical composition, also plant size and growing habit (Kask et al., 2005).

Materials and methods

The genetic resources collection is located in South Estonia at Polli Horticultural Research Centre (latitude 58°7`N and 25°33`E). The accessions at are preserved as trees in orchard. The collection has been compiled during a longer period with some

accessions dating back to 1945 and is being renewed constantly. During the inventory passport data were collected for the accessions and pheonological observations are made yearly. A back up (remote) orchard is being established on the western coast of Estonia in collaboration with an amateur gardener Raimu Aas, to safeguard the collection at Polli.

Results

Almost one thousand accessions have been planted into the collections including officially appreciated (registered) varieties and landraces and some selections of 17 tree fruit and small fruit crops. The plants are of different age, depending on the year of introduction. The replenishment of collections is in progress. Thus, the information that we possessed last year will become more perfect this year.

Besides the Russian Federation, some Western European countries, the USA and Canada, which have been the most important regions of introducing for a long time period, other countries are also indispensable for that purpose. For example, many prospective apple, plum and black currant cultivars originating in Belarus have been planted into the plantations of Estonia. Some good apple cultivars are originating in Finland and Lithuania. There are many apple clonal rootstocks bred in Poland, strawberry cultivars originating in the Netherlands, currant cultivars from Hungary. We should more thoroughly use the recent breeding results of our closest neighbour Latvia (apple, pear, plum, currant).

Genetic resources have been made useful in fruit and berry production in Estonia. For example, the "List of recommended for growing in Estonia fruit cultivars" has been supplemented with new cultivars during the years 2000 – 2007 (Table 2).

Cultivars bred in Estonia. Our goal was to collect all the cultivars, which were bred in Estonia and preserve them at Polli (Kask, 2004; Kask & Jänes, 2005; Kask & Jänes, 2006). However, we were not entirely successful. For instance, there are lacking 3 strawberry cultivars (50%), 2 black currant cultivars (14%), 7 plum cultivars (23%), killed by frost) and so on. Most of the winter damaged cultivars have been planted lately into the safeguard collection near the seacoast in West Estonia where the temperatures are less severe.

Estonia's tree fruit and small fruit cultivars have been important for fruit production more than a century. During the 20th century many cultivars originating in Estonia were included into the list of recommended cultivars for growing in our country and this number is increasing. In the "2008 List", there are 17 apple cultivars (10 of them bred at Polli), 5 pear cultivars (1 from Polli), 7 plum cultivars (5 from Polli), 8 sweet cherry cultivars (7 from Polli), 2 raspberry cultivars (from Polli), 1 white currant (from Polli), 1 black currant (from Polli), 1 gooseberry (from Polli), 6 cranberry cultivars (all from the Nigula Nature Preserve), 3 apple clonal rootstocks (all from Polli), and 1 pear seedling rootstock (from Polli) (Kask et al., 2007).

There are seventeen tree fruit and small fruit cultivars originating in Estonia, which are included into the analogous list of Latvian Republic. The most important are apple (5 cultivars) and sweet cherry (5 cultivars), the others are plum (3), pear (1), raspberry (2), and white currant (1).

The database of accessions maintained at Polli includes information of 253 cultivars and prospective selections, bred in Estonia and is accessible for researchers and other interested persons through the website of the coordinator of national program for genetic resources Jõgeva Plant Breeding Institute at http://www.sordiaretus.ee and Nordic Genetic Resource Centre. On-line catalogue of cultivars bred in Estonia can be accessed also at www.polli.ee. The accessions of Estonian origin are available to international collaborators for evaluation, research or breeding. This germplasm is distributed as scion wood or plants. Inventory and more detailed characterisation of our *Ribes* collections accessions, both Estonian and introduced cultivars, is being carried out within the EU plant genetic resources project "RIBESCO – Core collection of Northern European gene pool of *Ribes*".

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Table 1. The number of cultivars (accessions) of tree fruit and small fruit crops at the Polli Horticultural Research Centre in 2007

Crop	Number of cvs.	From these originating in							
		Estonia*	Russia	Belarus	Latvia	Lithuania	Finland	Rest of Europe	Canada and USA
Apple	330	38	140	10	15	10	15	40	50
Pear	97	7	33	2	2	3	0	8	1
Plum	81	22	30	5	1	0	0	14	6
Sweet cherry	62	15	8	1	0	3	0	2	0
Sour cherry	18	1	8	0	1	(1)	0	4	1
Strawberry	55	3	5	0	0	2	1	30	10
Raspberry	62	6	15	0	3	0	3	20	9
Black currant	97	12	30	7	0	9	6	27	0
Red currant	22	3	6	0	1	0	0	11	1
White currant	10	2	1	0	0	0	0	7	0
Gooseberry	30	7	11	0	1	1	5	4	1
Blackberry	2	0	0	0	0	0	0	1	1
Edible honeysuckle	15	0	15	0	0	0	0	0	0
Sea buckthorn	20	0	17	0	0	0	3	0	0
Rowan tree	17	0	14	0	0	0	0	3	0
Cranberry	5	5	0	0	0	0	0	0	0
Apple clonal rootstocks	23	6	5	0	0	0	0	12	0

* The number of breeder`s selections originating in Estonia is not shown here

Table 2. The number of cultivars supplemented in the "List of recommended for growing in Estonia fruit cultivars" in 2001 – 2007 (In the brackets: origin of cultivars*)

	2001	2004	2005	2007
Apple	5 (Bel 1, Can 1, Fin 1, Lat 1, Lit 1)	1 (Est)	7 (Est 4, Fin 1, Rus 2)	1 (Bel)
Pear	2 (Bel 1, Rus 1)		1 (Rus)	1 (Ukr)
Plum	2 (both Rus)		2 (Bel 1, Swe 1)	1 (France)
Sweet cherry			5 (all Est)	
Sour cherry			1 (Rus)	
Strawberry	5 (Can 1, Net 3, USA 1)			1 (Net)
Raspberry			2 (GB 1, Rus 1)	
Blackberry			1 (USA)	
Black currant	5 (Bel 1, Est 1, Rus 2, Swe 1)		3 (Bel 1, Fin 1, Swe 1)	
Red currant			1 (Lat)	
White currant	1 (Est)		1 (Swe)	
Gooseberry			2 (GB 1, Ukr 1)	
Seabuckthorn		1 (Rus)		
Cranberry	1 (Est)			
Blueberry	2 (both USA)			
Grape	3 (Lat 2, Rus 1)		3 (Lat 1, Rus 2)	2 (both Rus)

* Names of the states are abbreviated:
Bel – Belarus, Can – Canada, Est – Estonia, Fin – Finland, GB – Great Britain, Lat – Latvia, Lit – Lithuania, Net – the Netherlands, Rus – Russia, Swe – Sweden, Ukr – the Ukraine.

MOLECULAR MARKER APPLICATION IN BREEDING OF SELF- AND CROSS- COMPATIBLE SWEET CHERRY (*P. AVIUM* L.) VARIETIES

Gunārs LĀCIS, Silvija RUISA, Irita KOTA

Latvia State Institute of Fruit-Growing
Graudu 1, Dobele, LV 3701, Latvia
e-mail: gunars.lacis@lvai.lv

Abstract

The Latvian sweet cherry (*Prunus avium* L.) collection at the Latvia State Institute of Fruit-Growing comprises valuable material for breeding. The collection represents local Latvian genetic resources: semi-wild samples, landraces, and cultivars and hybrids developed in local breeding programme, as well as diverse germplasm from the northern temperate zone. Sweet cherry (*P. avium* L.) is a typical out-crossing species with a mono-factorial and multi-allelic gametophytic incompatibility system, therefore suitable pollinator is necessary in commercial orchards cultivars to ensure fertilization and subsequent fruit development. Another approach is development of self-compatible varieties adapted to local climate. All commercial cultivars of sweet cherries grown in Latvia are known to be self-incompatible. Another issue is to grow self-fertile cultivars, but these ones selected in warmer climate are not winterhardy enough at our country. Therefore in Latvia was started sweet cherry breeding programme, which is aimed to solve the problem of incompatibility and at the same time low winterhardiness. Breeding is performed by crossing cultivars – *Sf* gene donors with winterhardy local or introduced cultivars. Therefore, the aim of this investigation was to determine what cultivars and selections contain the most valuable in breeding *S*-alleles and to choose the most appropriate, cross-compatible crossing combinations, to clear up compatibility relationships among cultivars.

Genetic resources accessions and breeding material were screened for the presence of the self-incompatibility (*S*) S_1 to S_6 alleles, as well as self-compatibility allele $S_{4'}$ using PCR based typing. Acquired genotyping data of *S*-alleles was used in breeding for cross-compatible crossing combination planning as well as to clear up compatibility relationships among cultivars.

Key words: *Prunus avium* L., incompatibility alleles, *S*-RNase, allele-specific PCR

Introduction

Sweet cherry (*P. avium* L.) is a typical out-crossing species with a mono-factorial and multi-allelic gametophytic incompatibility system (Crane and Lawrence, 1929). In order to achieve high productivity, self-sterile sweet cherry cultivars have to be planted together with reciprocally compatible pollinator cultivars, blooming at the same time. In commercial sweet cherry orchards suitable pollinator cultivars ensure fertilization and subsequent fruit development. So it is important that *S*-genotype of cherries is known when planning sweet cherry orchard.

Pollen-incompatibility groups and *S*-alleles have been determined for many sweet cherry cultivars grown in the Western Europe and North America by using controlled crosses and by evaluating the number of fruit set and cytoembryological assessments of the pollen tube growth within the style. Based on crossing experiments, six widely

distributed sweet cherry *S*-alleles were determined (S_1 to S_6). These alleles have been used to constitute various sweet cherry cultivar incompatibility groups (Crane and Brown, 1937; Sonneveld et al., 2003; Tobutt et al., 2004).

All commercial cultivars of sweet cherries grown in Latvia are known to be self-incompatible. However, the identification of *S*-alleles in the Latvian collection has not been undertaken. Six sweet cherry cultivars were tested at Latvia State Institute of Fruit-Growing (LIFG, former Dobele HPBES) to investigate sweet cherry pollen compatibility with five pollinators by using *in vivo* and *in vitro* methods (Lacis et al., 2000). However, conventional breeding methods are time consuming and depending on weather during blooming.

Another issue is to grow self-fertile cultivars, but these ones selected in warmer climate are not winter-hardy enough at our country. To solve the problem of sweet cherry pollen incompatibility and at the same time low winter-hardiness, breeding programme is started by crossing cultivars – *Sf* gene donors with winter-hardy local or introduced cultivars.

Genetic diversity of sweet cherries in Latvia is high (Ruisa, 1998). They are widely distributed with a diversity of varieties in small gardens and commercial orchards, different from west European and North American ones. The Latvia State Institute of Fruit-Growing (LIFG) hold extensive valuable fruit crop genetic resources collections, including 135 accessions of sweet cherries, which are used both in research and breeding (Rashal and Lacis, 1999; Ruisa, 1999; Lacis et al., 2008).

In recent years, molecular methods based on PCR have been developed to speed-up the analysis of allele type. These methods have circumvented some of the problems associated with determining alleles from conventional controlled crosses (Tao et al., 1999; Hauck et al., 2001; Sonneveld et al., 2003). Several new *S*-alleles have been discovered by the molecular analysis. A total of 16 sweet cherry *S*-alleles have been identified from which 28 incompatibility groups were confirmed by Tobutt et al. (2004). Nevertheless crossing data would be very desirable for practical breeding purposes to verify the utility of each new *S*-allele.

Because LIFG collection contains very valuable selections, which can be used in breeding for specific purposes, information about their *S*-alleles could be very valuable in breeding programmes. One of the greatest priorities is to find the valuable alleles in the selections during early stage of the tree development – juvenile period, so fastening the process of seedling evaluation. Besides, PCR-based methods have been developed that enable *S*-alleles to be determined from vegetative material – leaves and buds. Therefore, the aim of this investigation was to determine what cultivars and selections contain the most valuable in breeding *S*-alleles and to choose the most appropriate, cross-compatible crossing combinations, to clear up compatibility relationships among cultivars.

Material and methods

Plant material. Accessions from sweet cherry genetic resources collections at the LIFG were tested. Most accessions in the collection in Dobele are local sweet cherry accessions acquired by P. Upītis – a famous Latvian horticulturist- and the main

collector of germplasm in the LIFG (Blukmanis et al., 1997; Lacis et al., 2008). Besides it many sweet and sour cherry varieties were introduced from Estonia, Lithuania, Belarus, Ukraine and Russia during soviet times.

Hybridisation. Pollens of sweet cherry cultivars 'Lapins', 'Rainier', 'Reverchon', 'Van' used in crossings, were received from France and Sweeden. Winter-hardy sweet cherry cultivars: 'Bryanskaya Rozovaya', 'Iputj', 'Aija' were crossed with the cultivars having large and firm fruits: 'Lapins', 'Rainier', 'Reverchon'. Potential parents were chosen as sources of genes for traits of importance in progenies: 'Van' transmit a short juvenile period, precocity, fruits of large size, and firmness to their progenies; 'Lapins' transmit self-fertility; 'Rainier' – good fruit quality; 'Reverchon' – cracking resistance. All hybrids were developed by conventional hybridisation.

Isolation of genomic DNA. Young leaves were taken in sweet cherry collection during May – June. Total DNA was isolated using the Genomic DNA Purification Kit (Fermentas, Lithuania).

S-allele genotyping. Genotyping of alleles S_1 to S_6 was performed as described earlier (Lacis et al., 2008). The S_4, allele was determined using primers developed by Zhu et al. (2004), using following PCR programme: 3 min at 94 °C, 35 cycles of 45 s at 94 °C, 1 min at 64 °C and 1 min at 72 °C, and one cycle of 10 min at 72 °C (Zhu et al., 2004).

PCR products were separated in agarose gels in 1X TAE buffer and visualized by staining with ethidium bromide. For amplification products with the SI 19/20 and SI 31/32 primer pairs, 2.0% agarose gels were used; products from the allele-specific primer pairs were separated in 1.5% agarose gels. A 100 bp DNA ladder (O'RangeRuler 100 bp DNA Ladder, Fermentas, Lithuania) was used for fragment size determination.

Data analysis. Significant differences were calculated using Student's t-Test in the MS Excel Data Analysis module.

Results

Sweet cherry breeding programme was started in 1998 at the LIFG. The two main goals are: to develop cultivars suited to our growing conditions with large, firm fruits and to develop self-fertile cultivars adapted to Latvia.

Our germplasm collection consists of 135 sweet cherry accessions, rich in genetic diversity. Since the winter-hardiness is one of the limiting factors for sweet cherry growing in our country, the following winter-hardy cultivars: 'Bryanskaya Rozovaya', 'Aija', 'Indra' and selection 24-10-22 were used as mother plants. 'Lapins', 'Rainier', 'Reverchon' and 'Van' were used as pollen cultivars. In total 7838 flowers were pollinated and 350 seedlings obtained. The parental combination 'Aija' x 'Van' gave 1 perspective hybrid, 'Aija' x 'Rainier' – 4 perspective hybrids, 'Bryanskaya Rozovaya' x 'Van' – 4 perspective hybrids, 'Bryanskaya Rozovaya' x 'Reverchon' - 2, 'Bryanskaya Rozovaya' x 'Rainier' – 1, 'Bryanskaya Rozovaya' x 'Lapins' – 2 perspective hybrids.

As a result of the evaluation 14 hybrids with dark red, firm fruits, weight of which varied from 5.2 to 8.6 g, with late ripening time were selected. These perspective hybrids are tested on Gisela 5 in the orchard of LIFG. From crosses of winter-hardy cultivar 'Iputj' with self-fertile 'Lapins' in 3 hybrids S_4, allele was found (Figure 1).

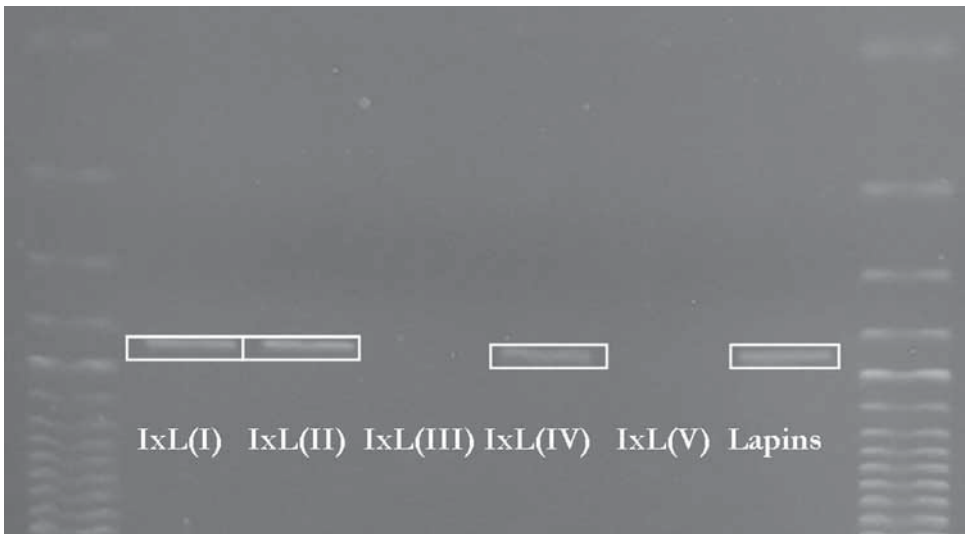

Figure 1. Self-compatibility allele (S_4) detection at the LIFG

Use of the degenerate *S*-RNase primer pairs (Wiersma et al., 2001) successfully detected the *S*-allele genotypes of 32 accessions in the LIFG collection. In cases where distinguishing fragments were unclear or where there was no PCR product, the *S*-RNase allele specific primer pairs (Sonneveld et al., 2001) were used to clarify *S*-genotypes. Forty-four accessions in the LIFG collection (Lacis et al., 2008) were identified using both methods. Two *S*-alleles were identified for each accession.

There were compared S_1 to S_6 alleles between the LIFG collection and global data, which include allele frequencies calculated from *S*-allele identification data over 250 sweet cherry cultivars from Western and Southern Europe published by Tobutt et al. (2004). The frequencies for S_1, S_2 and S_3 were not significantly different (Figure 2).

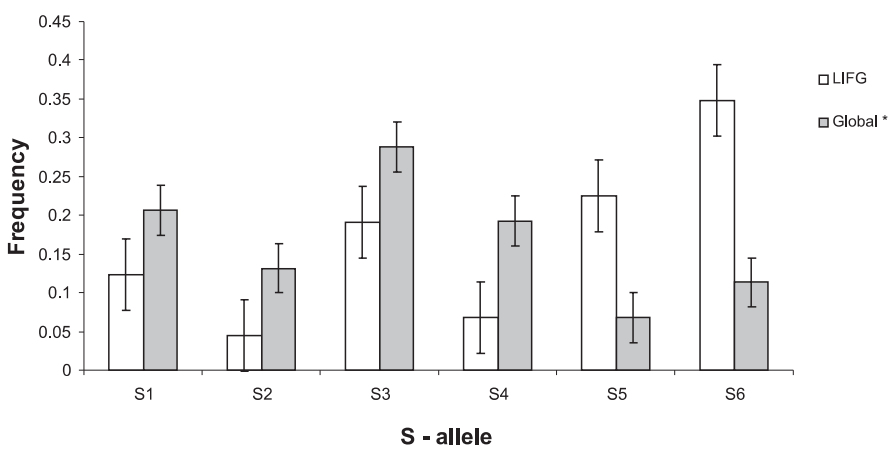

Figure 2. *S*-allele frequencies in accessions of the LIFG sweet cherry collection
(* - allele frequencies calculated from *S*-allele identification data published by Tobutt et al. (2004). Standard error bars shows the 0.95 confidence level ($P < 0.05$))

S_2 allele was the least frequent whereas the S_6 allele was the most frequent in LIFG collection. The comparison showed differences in the frequencies of the S_4 and S_5 alleles. The S_4 allele was very prevalent in global data, whereas S_5 allele was very prevalent in the LIFG collection.

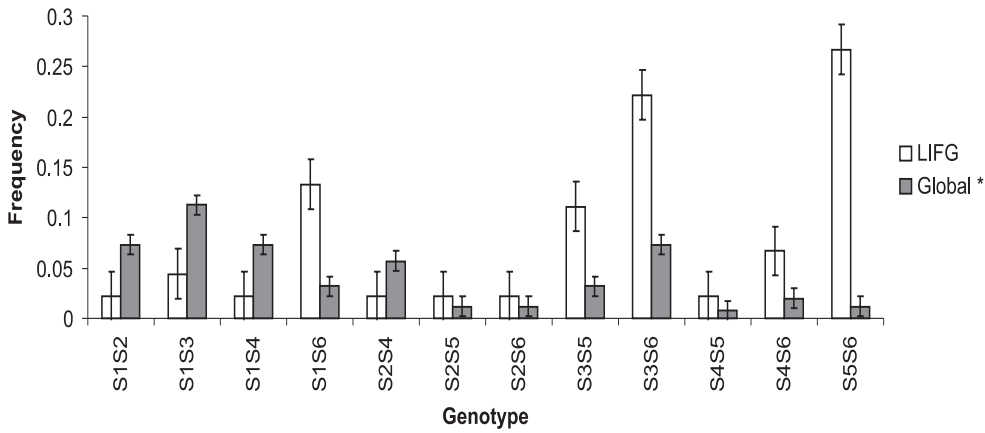

Figure 3. *S*-genotype frequencies in accessions of the LIFG sweet cherry collection
(* - genotype frequencies calculated from *S*-allele identification data published by Tobutt et al. (2004). Standard error bars shows the 0.95 confidence level (P < 0.05))

Twelve different genotypes were identified for the LIFG collection (Figure 3). There were no unique genotypes in the collection, previously not genotyped. The genotype S_3S_6 was detected at very high frequency in LIFG collection, whereas S_5S_6 genotype showed the highest frequency in the Latvian plant material. The genotype S_3S_4, which is frequent in the global data, was absent in the LIFG collection. The frequencies of the allele combinations identified were not consistent with the expected frequency from random mating population. For example, the detected allele frequencies of genotypes S_3S_6 and S_5S_6 in the LIFG collection were significantly higher than would be expected based upon independent segregation.

Discussion

The study represents S-allele determination for the sweet cherry genetic resources collections at LIFG. The $S_{4'}$ allele was identified in 3 selections, where self-fertile cultivar 'Lapins' was crossed with winter-hardy sweet cherry cultivar 'Iputj'. These selections will be further evaluated for winter-hardiness, yield, fruit quality and resistance to diseases. The valuable in sweet cherry growing allele $S_{4'}$ found in our selections will help to solve sweet cherry incompatibility problems in our country.

The LIFG collection is peculiar because the sweet cherry germplasm in this collection have sufficient winter hardiness to survive in Latvia. The differences in allele frequencies for S_4 and S_5 between the LIFG collection and global data are likely due to the diverse origins of the plant material. Previous works on *S*-allele genotyping, conducted by various authors (Bošković and Tobutt, 2001; Hauck et al., 2001; Sonneveld et al.,

2001; Wiersma et al., 2001; Sonneveld et al., 2003; Tobutt et al., 2004 and others) using sweet cherry germplasm, primarily of Western European origin plus modern varieties developed in Western Europe, Canada, and the U.S.

Bošković and Tobutt (2001) summarised the *S*-allele frequencies published at that time to be: S_3 (0.26), S_1 (0.17), S_2 (0.15), S_4 (0.13), S_6 (0.09) and S_5 (0.08). In a subsequent publication by Tobutt et al. (2004), *S*-allele genotypes for 247 sweet cherry varieties were presented; however, *S*-allele frequencies were not calculated. Our calculations based on data published by Tobutt et al. (2004) gave allele frequencies of S_3 (0.29), S_1 (0.21), S_2 (0.13), S_4 (0.15), S_6 (0.11), S_5 (0.07), which are similar to those published previously by Bošković and Tobutt (2001) and Tobutt et al. (2004).

Compared to the *S*-allele frequencies calculated from the 247 selections, the allele frequency of S_1, S_2 and S_3 was similar to that present in the LIFG collection. A high frequency of S_6 allele was identified in the material of P. Upītis' in the Dobele sweet cherry collection. The Dobele collection contains many locally well-adapted accessions with a high frequency of the S_6 allele.

According to Tobutt et al. (2004), 15 incompatibility groups or allele S_1 to S_6 combinations have been defined. The very high occurrence of the allele combination of S_3S_6 (0.22 in LIFG collection) and S_5S_6 (0.27 in LIFG collection) is in contrast to the low frequency of 0.07 and 0.01, respectively, reported by Tobutt et al. (2004)).

The higher occurrence of the S_6 allele in the LIFG collection and genotypes containing the S_6 allele poses an interesting question. Is the prevalence of the S_6 allele due to its presence in the founder clones that were widespread in Latvia or could the prevalence of S_6 be the result of linkage with alleles conferring adaptation to the northern European conditions?

Generating insights to these questions may be possible as *S*-allele genotypes for accessions in more sweet cherry collections become available. Additional genotyping of accessions with exactly known pedigree or use of mapping population with known S_6 allele carriers may confirm inheritance regularity of certain allele.

Conclusions

The *S*-allele information gained from this study will be useful in breeding programmes in the planning of crosses, for conservation of alleles and population genetics studies; to choose pollinator cultivars in planning of sweet cherry orchards.

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INVESTIGATION OF COLD HARDINESS OF SOME TEMPERATE CLIMATIC ZONE PLANTS *IN VITRO*

Vanda LUKOŠEVICIŪTĖ, Rytis RUGIENIUS, Gražina STANIENĖ, Irena ZALUNSKAITĖ, Danguolė KAVALIAUSKAITĖ

Lithuanian Institute of Horticulture, Kauno 30 LT54333, Kaunas distr. Lithuania
e-mail: r.rugienius@lsdi.lt

Abstract

Strawberry (*Fragaria ananassa*), quince (*Cydonia oblonga*), rape (*Brassica napus*) and many other agricultural and horticultural plants suffer from insufficient winterhardiness in Lithuania and other countries of temperate climatic zone. Unstable winter conditions often cause serious yield loss and decrease competitive ability of farms. Using *in vitro* methods it is possible to model temperature conditions of winter and screen plants by cold resistance and also perform investigations of cold resistance mechanisms. The aim of our work was to found optimal conditions of hardening and freezing *in vitro* for reliable genotype differentiation. 2 cultivars of strawberry, 3 clones of quince and 4 rape cultivars were used in the experiment. Influence of nutritional medium composition on rape plant survival rate after freezing was established. Optimal freezing temperature interval was from –9 to –11°C for rape microshoots genotype differentiation according to cold resistance *in vitro*, 'Valesca' was selected as the most cold resistant rape variety. Increase of sucrose concentration from 3 to 6% in the medium reduced cold injury of strawberry *in vitro* up to 20%. Raffinose (1%) and proline (0.001%) additions to the growing medium didn't significantly affect strawberry cold hardiness *in vitro.* After freezing *in vitro* at –9° C temperature, percent of quince (*Cydonia oblonga*) plants without cold injury varied depending on genotype between 5,4% (K16) and 28,2% (K19). Received data will be useful for further and wider screening and also for genetic engineering experiments with the aim to increase plant cold hardiness.

Key words: quince, cold resistance, oilseed rape, screening, strawberry, temperature

Introduction

Insufficient winter hardiness is one of the main problems for major fruit crops and varieties in temperate climatic zone. Under unfavourable wintering conditions, occurring almost every year, yield decrease of some widely grown strawberry varieties reaches 40 % (Nes, 1997). Unsatisfactory cold tolerance does not allow to show potential productivity of most fruit varieties.

Winter-hardiness and cold resistance in plants are determined by various genes, expression of these genes is interdependent. Factors that determine plant hardiness and cold resistance are not investigated sufficiently (Chinnusamy et al., 2007).

Cold resistance of rape as economically important species was investigated in various countries, and there was established a relationship between amount of certain enzymes (Zou Wang-hao et al., 2007), amount of growth regulators (Gaveliene et al., 2005), gene *hsp90* expression and accumulation of *hsp90* transcripts (Krishna et al., 1995) and between genotype and cold influence. Importance and peculiarities of cold acclimation of oilseed rape were described by Anisimoviene et al. (2005). Rape genotype

hardiness and cold resistance possibilities and methods *in vitro* are not investigated sufficiently.

Quince (*Cydonia oblonga*) is a popular dwarfing pear rootstock. However, insufficient cold hardiness limits its use for intensive pear orchards in Lithuania. In the Lithuanian Institute of Horticulture (LIH) several pear rootstocks were selected – quince clones that are compatible with most of pear varieties and quite adapted to our climatic conditions (Kviklys, 2000; Kviklys and Kvikliene, 2004). Effective and speedy screening system for cold hardy *Cydonia* is still necessary for new, perspective clone selection.

Plant tissue culture makes favourable conditions to model plant hardiness, to investigate expression of genes that influence plant hardiness and to examine physiological and biochemical mechanisms of this trait. Strawberry hardiness and cold resistance in *in vitro* conditions was started to investigate earlier and continues currently (Rugienius, Stanys, 2001; Lukoševičiūtė et al., 2007).

The aim of this work was to find optimal conditions of hardening and freezing *in vitro* for reliable genotype differentiation of strawberry (*Fragaria ananassa*), quince (*Cydonia oblonga*), rape (*Brassica napus*).

Material and methods

Experiments were performed in Plant Biotechnology Laboratory of LIH. Oilseed Rape cultivars 'Banjo', 'Elvis', SW 'Falstaff', 'Valesca', quince (*Cydonia*) genotypes K11, K16, K19 and strawberry cultivars 'Melody' and 'Venta' were used.

One month old rape seedlings that were germinated *in vitro* were transferred to climatic chamber with +2 – +4°C for cold acclimation. After 40 days cold acclimation rape seedlings were frozen *in vitro* at –7, –9 and –11°C temperatures for 12 hours, temperature was lowered gradually at 1°C/per hour speed. After freezing treatment seedlings were transferred to climatic chamber with +2°C for 24 hours. Microshoots isolated from seedlings and transferred to fresh MS medium (with or without vitamins and 3% sucrose). Rape plant state and survival rate were evaluated 1, 14 and 30 days after freezing. For the experiment 40 plants from each variety were used.

Strawberry plants (proliferous microshoots) before experiment were grown in flask (*in vitro*) on solidified standard Murashige and Skoog (MS) nutrient medium with addition of 1 mg/l BAP and 3% sucrose. Plants were grown in growing chamber with +22˚C temperature and 16 hour photoperiod. For the experiment they were transferred to test tubes with different variants of the media: 1) same as grown before - with 3% sucrose; 2) with 6% sucrose; 3) with 5% sucrose and 1% raffinose; 4) 6% sucrose and 0.001% proline. Strawberry plants (5 days after transfer to test tubes) were acclimated in +2 – +4˚C temperature for 35 days and freezed in –9˚C temperature for 12h *in vitro*. Plants were thawed at +4˚C temperature for 12 hours, replanted on standard MS medium in sterile conditions and cultivated in +22˚C temperature.

Cydonia plants were grown, cold acclimated and freezed in the same conditions as strawberry plants. MS nutrient medium with addition of 1 mg/l BAP and 3% sucrose were used. 10-30 microshoots in 3 repetitions of every cultivar for each variant were used. Evaluation of quince and strawberry plant survival rate (%) and cold injury (by scale – 0-not injured plants, 1- up to 5% tissue injured; 2 – 6-30% tissue; 3 – 31-70%

tissue; 4 – more than 71% tissue; 5- plants dead) was made one, two and three weeks after freezing. Statistical analysis was performed using ANOVA software.

Results

Freezing of rape microshoots *in vitro*. It was noticed that 24 hours after freezing *in vitro* rape seedlings on medium without additional vitamins differ in color – some of them turned yellow (Table 1). Most of green rape microshoots survived one month after freezing. Most of yellow microshoots had died during one month period after freezing. Only very few yellow microshoots of cultivar 'Valesca' survived, became green, started to grow again and gave new shoots.

Survival rate of microshoots of all investigated cultivars after freezing *in vitro* at –7°C temperature was 90-100%. Effect of lower (–9°C) temperature was highly dependent on genotype. 60% microshoots of cultivar SW 'Falstaff' survived during one month period after freezing at –9°C, 'Elvis' – only 20%.

There was noticed a relationship between plant survival rate after freezing and composition of used nutritional medium. All microshoots of investigated cultivars except 'Valesca', grown on MS medium without vitamins and frozen at –11°C temperature died during one month period after freezing. Some plants of all investigated cultivars grown on MS medium with vitamins survived during one month period after freezing at –11°C, even 50% of 'Valesca' microshoots survived (Figure 1).

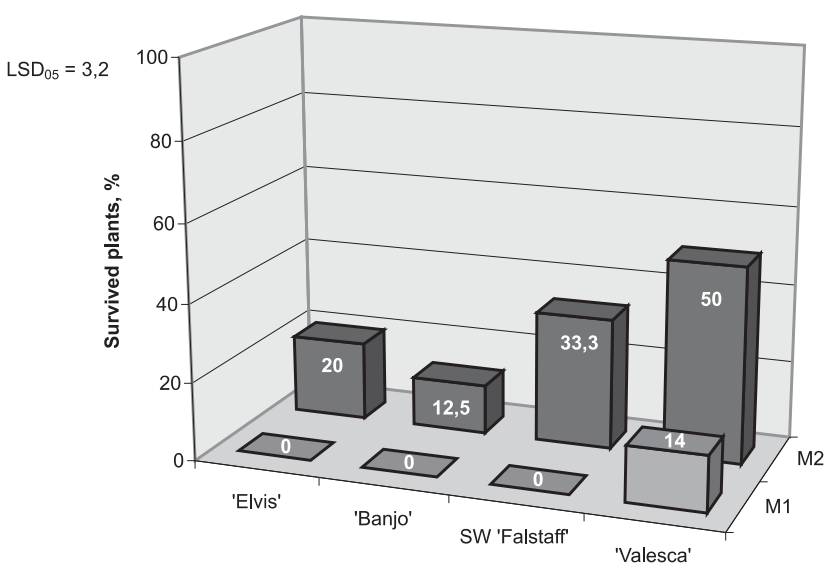

Figure 1. Survival rate of rape plants after freezing *in vitro* at –11°C temperature, depending on cultivar and medium. (M1 medium without vitamins, M2 – with vitamins)

Freezing of strawberry microshoots *in vitro*. The aim of this study was to evaluate cold resistance of strawberry *in vitro* depending from osmoprotectant additions (carbohydrates sucrose and raffinose and amino-acid proline) to the growing medium.

According to our data double increase of sucrose concentration in the medium led to decrease of cold injury of strawberry *in vitro* by 20%. When sucrose concentration in the media was 3% (near optimal concentration for strawberry micropropagation), cold injury of 'Melody' plants reached 4.9 score, when sucrose in the medium was 6%, cold injury decreased to 3.9 score (Figure 2). Effect of raffinose with sucrose addition to the medium was unambiguous to the cold hardiness *in vitro*. The effect was genotype dependent – cold injury level of 'Venta' plants was almost the same as in the medium with 3% sucrose (4.9 score), cold injury of 'Melody' plants (4.2 score) was less than in the variant with 3% sucrose but higher than in variant with 6% sucrose. For both cultivars cold injury score in the variant where sucrose 6% with proline 0.001% were added to the medium was slightly lower than in the variant with 3% sucrose alone, but the difference between those two variants was not significant statistically.

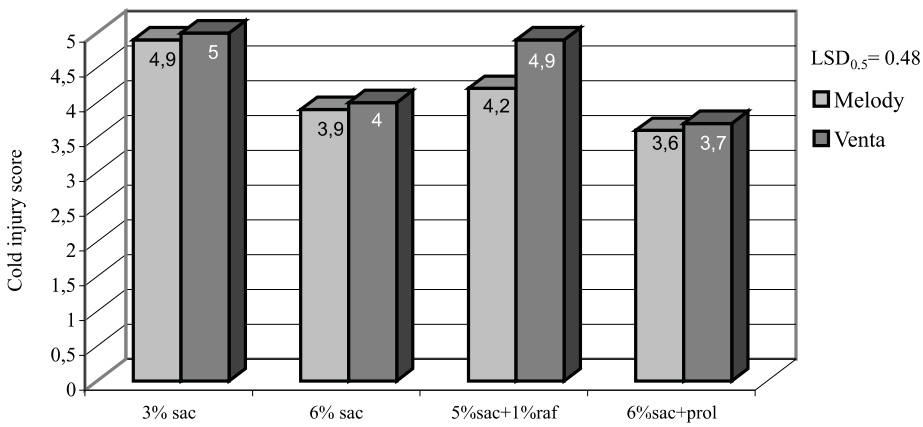

Fig 2. Cold injury of strawberry 'Melody' and 'Venta' plants *in vitro* depending on osmoprotectant (carbohydrates and proline) content in the medium.

Freezing of quince (*Cydonia*) microshoots *in vitro*. Differences between investigated quince genotypes by cold resistance *in vitro* were not so considerable like in strawberry and rape. Quince K19 plants were least cold injured after freezing at -9°C temperature *in vitro* (Table 2). Average cold injury score of K19 was 1.6. Cold injury of quince K16 was highest and reached 2.1 score. Cold resistance of K11 was somehow in between – cold injury score 1.8. Cold injury level of quince fully revealed itself only 3 weeks after freezing *in vitro*. In comparison – cold injury score of quince K11 one week after freezing had 1.4 score; after 2 and 3 weeks 1.9 and 1.8 respectively. Differences of quince genotypes by cold resistance were more prominent when taking in to account rate of plants without cold injury. Percentage of quince plants without cold injury varied depending on genotype between 5.4% (K16) and 28.2% (K19) (Figure 3). Genotypes K11 and K19 are closer to each other by cold resistance, while K16 is distinguished by lowest rate of not cold injured plants. If certain quince plant is cold damaged or not became full evident not earlier than 3 weeks after freezing. Rate of not injured plants during three weeks of evaluation decreased from 43.6 to 28.2% (K19) and from 35 to 20% (K11).

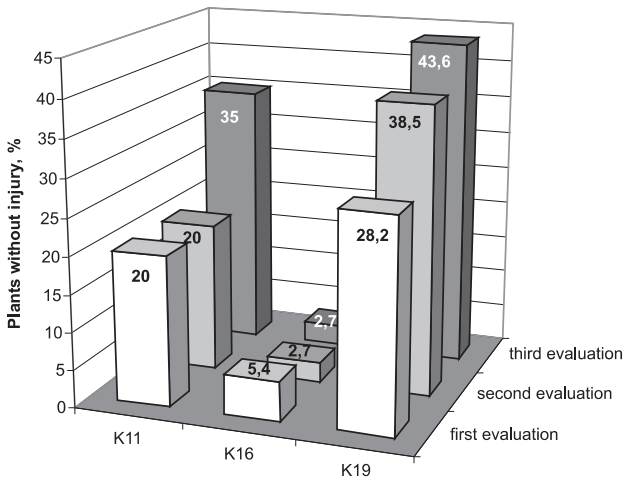

Figure 3. Rate of K11, K16, K19 quince plants without cold injury after freezing *in vitro*, three different evaluations.

Discussion

During our investigations it was shown that optimal freezing temperature for rape (*Brassica napus*) genotype differentiation by cold resistance *in vitro* ranges between –9 and –11°C. This is close to other investigations where LT_{50} for three rape cultivars ranged between –8 and –11°C (Rife, Zeinali, 2003). Freezing experiment data of different rape cultivars received in our studies helps us to choose genotypes for further cold resistance studies of this industrially important crop using molecular markers or genetic engineering. Another important finding in our investigation was dependence of rape cold hardiness *in vitro* from vitamins to the medium. Addition of vitamins to the growing medium helps rape plants to survive much lower temperatures. It once again shows the importance of physiological and biochemical conditions for cold acclimation and hardiness of plants. It must be analyzed in further studies.

Importance of medium content for cold hardiness *in vitro* was shown for strawberry as well. Especially interesting it is to evaluate the potential role osmoprotectants in not fully acclimated plants. It is important to know if it possible by increasing osmoprotectant content in the medium (or in the plant) reach the same or even higher cold hardiness level as using long lasting cold acclimation. According to the data of our previous studies, strawberry full acclimation takes no less than 30 days (Rugienius, Stanys, 2001). According our present results, sucrose is one of most potential osmoprotectants – increase of sucrose concentration from 3 to 6% in the medium reduces cold injury up to 20%. Despite that some authors indicate that raffinose has protective role for plants in low temperatures (Kalberer et al., 2006), in our study we didn't noticed positive effect of raffinose on cold resistance of strawberry *in vitro.* Possible function of this suggar is to protect membranes from freeze-induced desiccation stress (Pennycooke et al., 2004). Often it is not clear in natural conditions if the change in carbohydrate content

in plants during acclimation is due mechanism of adaptation or is as consequence of temperature change itself. Descriptive physiology has a limited ability to unravel cause and effect relationships. The use of molecular genetic tools, coupled with proteomics and metabolomics of cold hardiness transitions (to document more variables than traditional physiology) could aid in separating mechanisms from fortuitous correlations (Kalberer et al, 2006).

Also, no considerable protective effect of 0.001% proline addition to the media was found. Some authors notice correlation between the increase of proline levels with increase of cold resistance of plants (Duncan, Widholm, 1987). According to other authors, role of this amino-acid remains controversial - proline more likely serves as cold stress indicator than cryoprotectant or osmoprotectant and doesn't correlate with cold hardiness (Yelenosky, 1979 YaJun et al, 2004).

There are not many quince (*Cydonia*) cultivars introduced so far, therefore gene pool of quince used for cultivation is not wide enough. One of criteria of selection of K11, K16 and K19 quince clones in LIH were their adaptivity to local climatic conditions. It could explain that no big differences in cold resistance were observed in our *in vitro* freezing experiments. Anyway *Cydonia* genotypes could be differentiated *in vitro* by cold hardiness. Number / percent of plants without cold injuries could be a good genotype differentiator of quince.

It was hardly possible to diversificate quince plants credibly by cold hardiness until 3 weeks pass after freezing, so cold injury evaluations should start not earlier than this period. Those suggestions are valid for strawberry and rape as well. According these and earlier experiments, optimal temperature for quince genotype discrimination for cold hardiness is -9- -12 °C. The data helps us to choose quince genotypes for further investigations and genetic engineering experiments with the aim to increase cold hardiness of that quite new in Lithuania, but perspective (especially as dwarfing rootstock for pears) crop.

Conclusions

Influence of nutritional medium composition on rape plant survival rate after freezing was established. Optimal freezing temperature interval was from -9 to -11°C for rape microshoots genotype differentiation according to cold resistance *in vitro*, 'Valesca' was selected as the most cold resistant rape cultivar.

Increase of sucrose concentration from 3 to 6% in the medium reduced cold injury of strawberry *in vitro* up to 20%. Raffinose (1%) and proline (0.001%) additions to the growing medium didn't affect significantly strawberry cold hardiness *in vitro.*

After freezing *in vitro* at -9°C temperature percent of quince (*Cydonia oblonga*) plants without cold injury varied depending on genotype between 5,4% (K16) and 28,2% (K19).

Acknowledgements

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Table 1. Survival rate of rape microshoots of different cultivars after freezing *in vitro* (MS medium without vitamins)

Cultivar	Freezing temperature, °C	Microshoots after 24 h		Survival rate after	
		green, %	yellow,%	14 days, %	30 days, %
'Elvis'	-7	100	0	100	90.0
	-9	100	0	30.0	20.0
	-11	10.0	90.0	0	0
'Banjo'	-7	100	0	100	100
	-9	100	0	100	55.5
	-11	0	100	37.5	0
SW 'Falstaff'	-7	100	0	90,0	90.0
	-9	100	0	60,0	60.0
	-11	0	100	0	0
'Valesca'	-7	100	0	90.0	90.0
	-9	100	0	60.0	50.0
	-11	28.6	71.4	28.6	14.3
LSD_{05}		1.3	1.4	2.8	2.9

Table 2. Distribution of quince microshoots according to injury level (score) after freezing *in vitro*

Cold injury score	Genotypes								
	K 11			K 16			K 19		
	1*	2**	3***	1*	2**	3***	1*	2**	3***
0	14	8	8	1	1	2	17	15	11
1	7	15	15	17	15	14	9	9	11
2	11	3	3	9	9	8	7	6	8
3	5	6	7	6	6	6	3	4	3
4	3	4	5	3	4	6	2	3	5
5	0	4	2	1	2	1	1	2	1
Average score	1.4	1.9	1.8	1.9	2.1	2.1	1.2	1.4	1.6

* first evaluation (one week after freezing),
** second evaluation (two weeks after freezing),
*** third evaluation (three weeks after freezing)
LSD_{05} = 5.9

INFLUENCE OF WEATHER CONDITIONS ON APPLE FLOWERING

Florin STĂNICĂ, Adrian PETICILĂ, M.DUMITRAŞCU

Research Center for Integrated Fruit Growing Faculty of Horticulture
University of Agronomic Sciences and Veterinary Medicine, Bucureşti, România
e-mail: flstanica@yahoo.co.uk

Abstract

Apple is the leading species in Romanian fruit growing and Voineşti area is one of the most favorable and well known for apple production. The climate changes influence more and more the fruit tree development and the study of influence of the climatic conditions on fruit production is very important for researchers and growers. 20 private apple farms from Voineşti area were monitored during the flowering period in order to investigate air and soil temperature influence on timing of the main spring phenophases. The studied period was ranged in 12 stages, from the dormant flower bud to walnut-like fruits size. To study the floral biology and physiology changes, two apple cultivars 'Golden Delicious' and 'Jonathan' were evaluated. Age of monitored trees varied from 5 to 40 years. The climatic data were registered from two local meteorological stations. The dynamic of apple tree phenophases was correlated with air and soil temperature, location, variety and tree's age.

Key words: *Malus domestica,* cultivars, climate changes, air temperature, soil temperature, phenophases

Introduction

Apple is the leading species in Romanian fruit growing and Voineşti area is one of the most favorable and well known for apple production. The climate changes influence more and more the fruit tree development and a study of the influence of climatic conditions on fruit production is very important for researchers and growers (Armeanu et al., 2007).

Materials and Methods

Voineşti area is located on Dâmbovița Valley not far from the Southern chain of the Carpathian Mountains at 45° 08' N latitude, 25° 23' E longitude and 400 m altitude.

20 private apple farms from Voineşti area were monitored during the flowering period in order to investigate air and soil temperature influence on timing of the main spring phenophases (Figure 1).

The studied period was ranged in 12 stages, from dormant bud to bud breaking, rosette formation, petal appearance, red button, petal formation, first flower opened, mass blossom, petal dropping, fruits pea seed size, fruits hazelnut size and walnut-like fruit size (Figure 2).

To study the floral biology and physiology changes, two apple cultivars: 'Golden Delicious' and 'Jonathan' were evaluated. Age of monitored trees varied from 5 to 40 years. The climatic data have been registered from two local Vaisala meteorological stations.

Figure 1. Voineşti – Traditional apple orchard

Figure 2. Natural apple thinning

Results and discussion

The dynamic of apple tree phenophases was related with air and soil temperature, location, variety and tree's age, under similar cultural practice conditions.

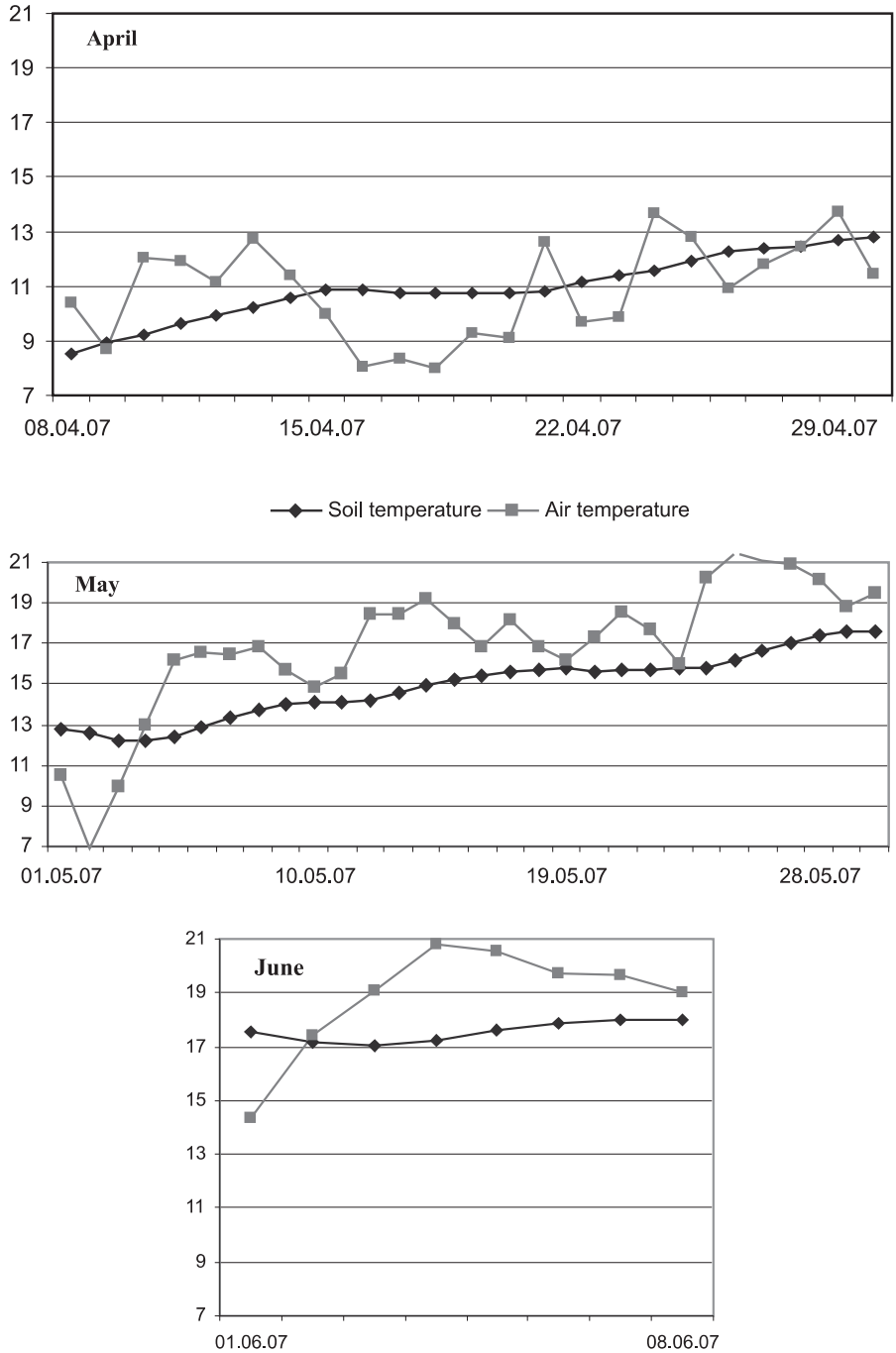
Analyzing the dynamic of soil and air temperature between April and June (Figure 3) it is possible to see two different curves. Soil daily temperature had quite a constant increase meanwhile the air temperature was extremely variable. Only in June the air temperature was constantly higher that the soil one (Figure 4).

The evolution of the fruiting phenophases was influenced by location, with a delay of around 5 days in 30 km to north, along the Dâmbovița Valley. Between the two cultivars, 'Jonathan' and 'Golden Delicious' differences of 4-5 days in blossom start has been recorded in the same location at trees of the same age (Table 1).

Comparing the decadal temperature recorded in Voinești in 2007, with the Typical Meteorological Year values, statistically determined, is obvious that for more than 300 days the records were bigger (Figure 5).

The typical meteorological year was calculated using all characteristics which presents an high interest for a certain field activity. Each month of a typical year is a true

(effective) month from one of the considered years to build the typical year and is not an average of the mesure data for some many years (1).



Figures 3 a,b,c. Dynamics of air and soil temperatures °C in Voineşti area
(a – April, b – May, c – June)

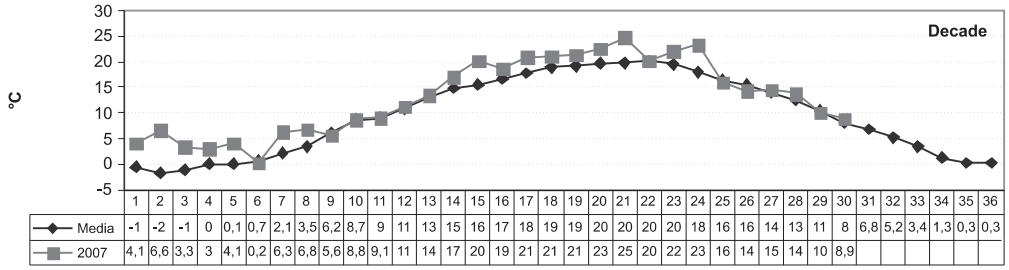


Figure 4. Decadal temperatures °C in Voinesti area in 2007, in comparison with the Typical Meteorological Year values

Conclusions

The analysis of the climate in Voinesti area in 2007 compared to previous years showed that the temperature has more and more extreme value that can affect the fruit tree physiology.

Early higher temperature during the spring frequently caused important damages because of the late frosts that can affect the apple flowers.

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Table 1. Dynamics of apple phenophases in Voineşti area in relation with average soil and air temperature

Phenophase / Cultivar	Starting date	Soil temp., °C	Air temp., °C	Starting date	Soil temp., °C	Air temp., °C
	Jonathan			Golden Delicious		
A. Dormant bud	10.03	7.14	8.90	10.03	7.14	8.90
B. Bud breaking	20.03	8.52	10.12	24.03	8.80	9.52
C. Rosette formation	03.04	9.05	10.25	03.04	9.05	10.25
D. Petal appearance	10.04	9.25	12.04	15.04	10.85	10.01
E. Red button	14.04	10.56	11.41	20.04	10.73	9.14
E1. Petal formation	18.04	10.72	7.97	22.04	11.15	9.72
F. First flower opened	22.04	11.15	9.72	27.04	12.40	11.82
F1. Mass blossom	24.04	11.54	13.65	30.04	12.83	11.42
G. Petal dropping	05.05	12.41	16.18	10.05	14.09	14.89
G1. Fruits pea seed size	15.05	15.21	17.93	20.05	15.65	17.35
H. Fruits hazelnut size	30.05	17.60	19.45	02.06	17.15	17.39
I. Fruits walnut size	26.06	19.90	25.20	24.06	19.75	23.45

Part C

"ORCHARD MANAGEMENT FOR SUSTAINABLE FRUIT PRODUCTION"

SOIL MANAGEMENT SYSTEMS IN ORCHARD INCLUDING GROWING GRASSES, USE OF HERBICIDES, MULCHING AND NITROGEN FERTILIZER

Ivars DIMZA, Arnolds GROSS, Māra SKRĪVELE, Edgars RUBAUSKIS

Latvia State Institute of Fruit-Growing
Graudu 1, Dobele, LV-3701, Latvia
e-mail: lvai@lvai.lv

Abstract

In a state farm in the vicinity of town Tukums, Latvia in the years 1979 – 1989 a four factor trial with apple cultivar 'Antonovka' on seedling rootstocks was carried out. The lay-out of the plots was split – split – split – plot design. There were several factors and their levels: first were soil management methods in the alleyway – tillage or growing perennial grass. The three remaining factors were applied to comparatively broad strips around the trees: mulching – none, peat, the mowed grass; simazine – 5 or 10 kg·ha^{-1} a.i.; nitrogen fertilizer – 0, 80, 160 kg·ha^{-1} N. All the combinations of these factors made up 36 treatments. Growing grasses in the alleyways, which were mowed only two times in a season slightly diminished the yield of apples and the vegetative growth of the trees. The detrimental effect of grasses was stated only in the on-years of alternative bearing apple trees. Besides, the negative effect of two times mowed grasses may be overcome by sufficient doses of nitrogen fertilizer and effective controlling weeds by herbicide. Consequently, in connection with these factors the number of mowing the grass in alleyways could be considerably reduced: even to two. This would be more economical than frequent mowing of grasses. Peat mulch had negative influence on growth and cropping of the trees. This was connected with adsorbtion and inactivation of simazine, consequently, with enhanced growth of weeds. This negative effect of peat mulch was greatly overcome by nitrogen fertilizer. Also the negative effect of peat mulch was less pronounced, when the soil in the alleyways was cultivated. Thin layer of mulch of mowed grass did not influence either the cropping, or growth of the trees. The simazine had improved the availability of nitrogen for fruit trees.

Key words: *Malus*, herbicide, mulch, sod, nitrogen fertilizer

Introduction

In the alleyways of modern intensive orchards perennial grasses are grown and frequently mowed, but around the trees narrower or broader strips are maintained free from any vegetation. As means of controlling weeds in the tree strips still recently herbicides were applied (Baxter and Newmann, 1971; Atkinson, 1977; Schupp, 1996). Nevertheless, the use of herbicides, especially the pre-emergency ones, in the last years is more or less limited because of their possible negative effect on the soil and fruits. Therefore alternative methods of weed control, as for example, thermal means – flame and hot steam – are searched (Rifal et al., 2002). The most applied method, however, is mulching the tree strips (Hartley et al., 1996; Olivera and Merwin, 2001; Rifal et al., 2002; Neilsen et al., 2003).

The goal of our experiment was to test the effect of mulching the soil in the tree strips, various doses of simazine and also nitrogen fertilizer in a traditional orchard

with apple cultivar 'Antonovka' on seedling rootstocks.

Although the herbicide, mulch and various doses of nitrogen were tested in a traditional (extensive) orchard, we hope that some conclusions gained and also failures of our experiment may be useful also for modern fruit growers.

Material and methods

A four factor trial with apple cultivar 'Antonovka' on seedling rootstocks was carried out in the vicinity of town Tukums, Latvia, in a state farm during the years 1979 – 1987.

The orchard was situated on an elevated plain with excellent air drainage and soddy-podzolic sandy-loam soil and sandy loam subsoil. The apple trees were planted in 1970, the spacing was 4 × 8 m. The lay-out of the plots was orthogonal split-split-split-plot design. There were four factors with two or three levels. The first one was soil management methods in the alleyways – tillage or growing perennial grasses that were mowed only two times in the growing season. The tree remaining factors were applied to 3.5 m broad strips around the trees: mulching – none, peat (5 cm think layer), the mowed grass; simazine – 5 or 10 kg·ha^{-1} active ingredient (a.i.), nitrogen fertilizer – 0, 80, 160 kg·ha^{-1}. All the combinations of these factors made up 36 treatments that were arranged in three blocks, respectively – replications. In each plot there were 10 trees.

The potassium and phosphorus available for plants were determined by the method of Egner-Riem, the soil pH in a 1n KCl extract. The soil and the fruits were analyzed for the residues of simazine, but for residues of nitrates only the fruits. The rate of flowering, cropping as well as the amount of weeds were evaluated visually (points 0 – 10). Statistical evaluation of obtained data was carried out by the variance analysis and also multiple regression analysis.

Results

Growing grasses in the alleyways that were mowed only two times in growing season had a negative although statistically insignificant effect on growth and cropping of the trees (Table 1).

The peat mulch greatly enhanced the growth of weeds in the tree rows, and thus adversely affected growth and cropping of the trees. The negative differences due to peat mulch were significant for the increase of trunk circumference, yield (kg per tree) and highly significant ($p<0.01$) for visually evaluated rate of cropping. Highly significant was also diminishing of leaf green that may be evidence for nitrogen deficiency.

The double dose of simazine (10 kg·ha^{-1} a.i.) in comparison to ordinary one (5 kg·ha^{-1} a.i.) significantly diminished the amount of weeds in the strips, but did not affect the parameters of tree growth and cropping. The ground around the trees after application of simazine in double dose was almost free from weeds and grasses, yet covered by a moss carpet. Besides, the leaves of the trees were darker green than the leaves of trees were the lower simazine dose was applied. The positive effect of nitrogen fertilizer on all parameters of growth and cropping – also the rate of flowering – was highly significant ($p<0.01$). The colour of leaves was also importantly improved. Without this fertilizer the apple leaves were yellowish green; that was an evidence of distinct nitrogen deficiency. Besides, the nitrogen was not applied in such a rate that might adversely affect growth

and cropping of the trees. Doubling the nitrogen dose (from 80 to 160 kg·ha^{-1} N) significantly influenced only the rate of leaf green: the leaves were dark green. The rate of flowering, rate of cropping, yield, and increase of trunk circumference were similar for both nitrogen doses.

However, the main effect of the factors does not fully reveal the real relationships in these four factor trial. This can be attained by calculating interactions of the factors. Significant was the effect of the interaction of soil management in alleyways and mulching soil in tree strips on the visually evaluated rate of cropping (Figure 1). When the soil in alleyways was cultivated, the detrimental effect of the peat mulch in herbicide strips was minimal, but when the alleyways were grassed this effect was significantly more pronounced. The influence of the thin layer of grass mulch on the yield intensity in comparison to bare soil was insignificant on both backgrounds. The interaction of these factors on the obtained yield (kg per tree) had similar tendencies, but because of great chance variation it can not be statistically proved.

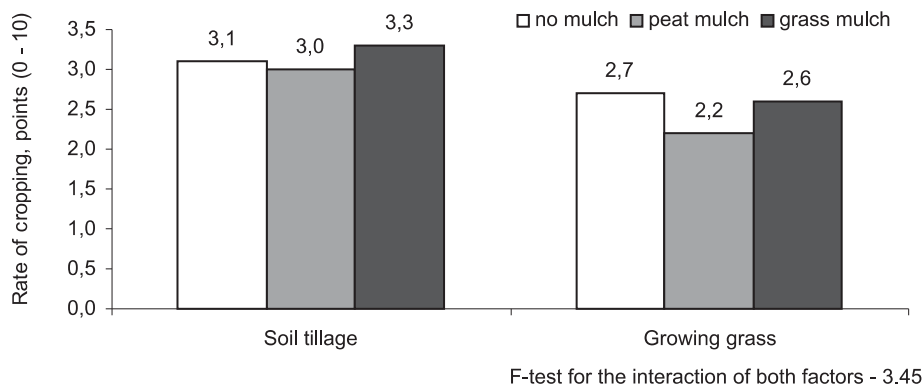

Figure 1. Influence of soil mulching on the yield intensity of apple trees of cultivar 'Antonovka' in dependence of the method of soil management in alleyways (1982 – 1985)

The interaction of soil management methods and nitrogen fertilizer (Figure 2) shows that this nutrient had much more enhanced growth and cropping of 'Antonovka' apple trees when grasses grew in the alleyways than when there the soil was cultivated. On the background of the cultivated alleyways the nitrogen fertilizer had not at all influenced the growth of trunks. Doubling the dose of nitrogen fertilizer (from 80 to 160 kg·ha^{-1}) also on the background of grassed alleys did not enhance either the growth, or cropping of the trees.

More detailed outlook on the complex influence of the factors one can obtain from the second-order interaction: method of soil management × nitrogen fertilizer × cropping periods (Figure 3). In the first two-year period (1980 – 1981) when the trees were relatively young the detrimental effect of grasses in the alleyways on the yield was very strong independently of the application of nitrogen fertilizer – either of the lower or higher doses. On the contrary, in the next period (1982 – 1983), nitrogen remarkably diminished the adverse effect of grasses. Besides, the yield in all treatments was considerably higher as in the former period. Still more pronounced interaction of

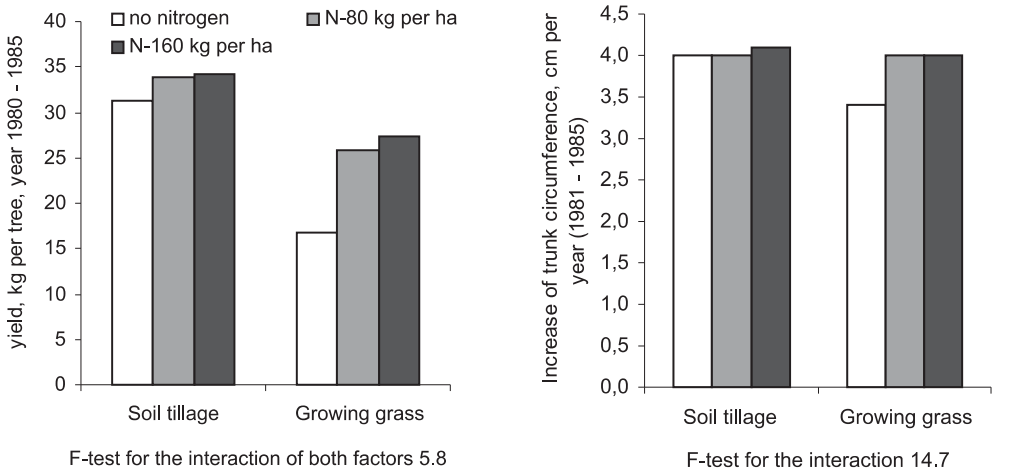

Figure 2. Influence of nitrogen fertilizer on the yield and growth of apple-trees of cultivar 'Antonovka' in dependency of methods of soil management in alleyways

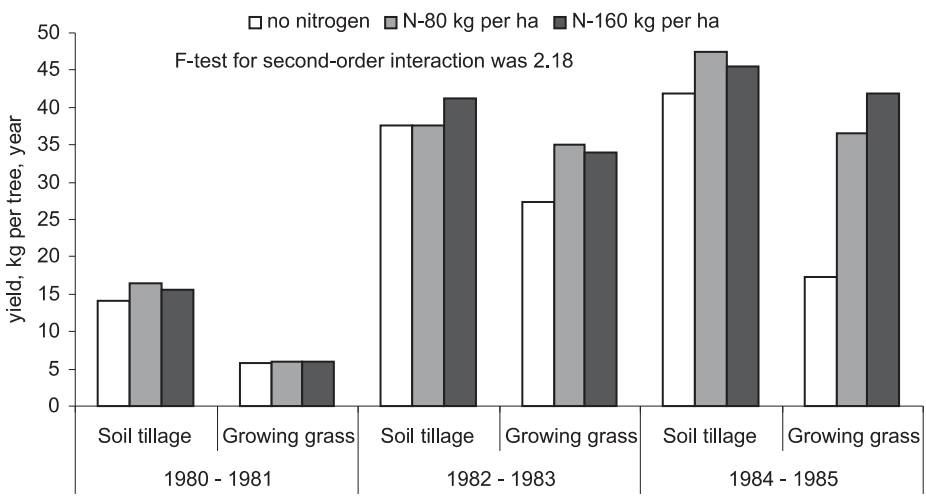

Figure 3. Effect of nitrogen fertilizer on the yield of apples of cultivar 'Antonovka' in dependence of the soil management in alleyways in three cropping periods

soil management and nitrogen fertilizer was in the third period (1984 – 1985). On the background of grassed alleyways under the influence of nitrogen, particularly in the highest dose, the yields increased more than two times, whereas on the background of soil tillage the effect of this nutrient was minimal.

The interaction of nitrogen fertilizer and dose of simazine was significant only for the visually evaluated leaf green and the increase of trunk circumference (Figures 4 and 5). The higher was the dose of nitrogen, the lesser was the effect on both parameters of doubling the dose of simazine. Without nitrogen and with the lower dose of simazine the apple leaves were yellowish green – an evidence of nitrogen deficiency. On the contrary, where the highest dose of nitrogen (160 kg·ha^{-1}) and either the lower or higher dose of simazine were applied the leaves were healthy green with no deficiency symptoms.

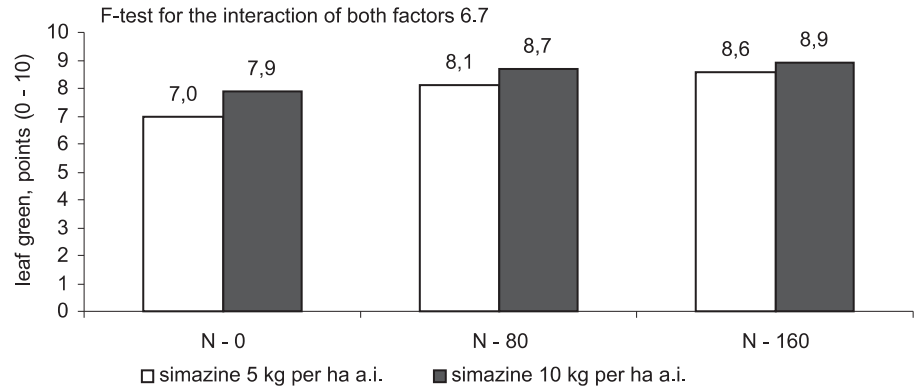

Figure 4. Interaction of nitrogen fertilizer and doses of simazine on leaf colour of apple cultivar 'Antonovka' (1982 – 1984)

Figure 5. Interaction of nitrogen fertilizer and doses of simazine on trunk growth of apple cultivar 'Antonovka' (1981 – 1985)

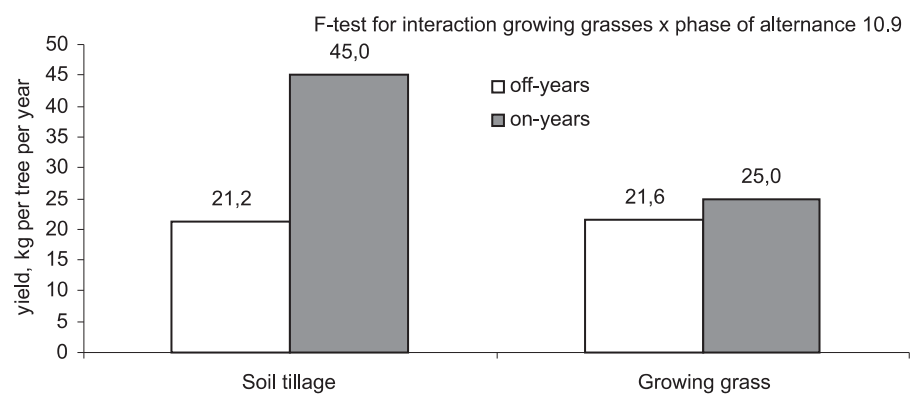

Figure 6. Influence of growing grasses in alleyways on the yield of apple cultivar 'Antonovka' in dependence of the phase of alternance of bearing (1980 – 1985)

Highly significant was the interaction of the method of soil management in the alleyways and the phase of alternance of bearing (Figure 6). The detrimental effect of grasses on the cropping of apples was pronounced only in the on-years, when the yield of apples in the plots with cultivated alleyways was almost twice as high as in plots with grass between tree rows. On the contrary, the moderate yields in the off-years were nearly equal independently of soil management in the alleyways. Consequently, in the treatments with grassed alleyways the trees were bearing evenly although not abundantly.

The residues of simazine in the apples were negligible, even in the treatments with higher dose of this herbicide – only 3 $\mu g \cdot kg^{-1}$, that is 1.5 per cent of the maximal admitted amount. The apple roots under the peat mulch evidently absorbed even less herbicide, and its concentration in the fruits was still less – 0.8 $\mu g \cdot kg^{-1}$ (Table 2).

Discussion

The negative influence of the grasses in the alleyways on growth and cropping of the trees may be explained by the fact that they were mowed only two times in the growing season. This enhances the competition of grasses with fruit trees for water and nutrients, especially nitrogen. In modern orchards this competition is overcome by destroying weeds in the tree strips and frequent mowing of grasses in the alleyways – e.g. at 10 – 14 day intervals (Atkinson, 1977). In our trial the rare mowing was adjusted to real economical circumstances at the state farms in the time when the experiment was carried out. However, one could suppose that the herbicide treated tree strips were broad enough – 3.5 m or 44 per cent of the whole area – to furnish the trees with sufficient amounts of water and nutrients. In modern intensive orchards with narrow inter-row space the tree strips are also narrower. For example, in an orchard with a 3.5 m distance between rows the weed free strips were 2.0 m wide that is 57 per cent from the whole area (Neilsen et al., 2003). In another orchard with 5 m distances between rows the tree strips were also 2.0 m wide or 40 per cent of the orchard area (Hartley et al., 1996). However, in the recent years because of environmental reasons a tendency to reduce the width of the herbicide strips becomes apparent, in some cases even to 0.3 m (Hipps and Perring, 1989). It is since long known that the roots of vigourous apple and pear trees grow much further as the projection of their canopy. Consequently, a relatively great part of apple roots in our trial were situated in the alleyways, that is, under the grass cower. On the contrary, the roots of dwarfing rootstocks grow more compactly near the trunk (Surikova et al., 2008). It could be supposed that supplementary doses of nitrogen would eliminate the adverse effect of competition of grasses for this nutrient. However, data in literature on this subject are controversial. Baxter and Newman (1971) stated: "Using more nitrogen fertilizer did not compensate for the grass competition and did not increase growth or yield". On the contrary, Raese (1991) found that "moderate or high rates of supplemental N fertilizer overcome interference (competition) from weeds". In our trial lucidity on this subject should be brought about by the interaction of nitrogen fertilizer and soil management methods, which was highly significant both for yield and trunk growth (Figure 2). The nitrogen fertilizer wholly eliminated the adverse effect of grasses on the trunk growth, but only partially on the yield. Consequently,

evidently there are other causes – the grass competition for water, as the orchard of our trial was without irrigation. More light on this problem maybe cast by the second-order interaction, which besides the two factors mentioned above, includes also three two-year periods (Figure 3). In the first period (1980 – 1981) when the trees were 10 – 11 years old, nitrogen did not eliminate the very strong adverse effect of grasses. That proves that in this period the real cause of this adverse effect was the depletion of moisture under the grass. The longer was duration of trial, the more nitrogen application eliminated the depressing effect of grasses. Evidently, during the long course of the experiment depletion of nitrogen in the soil did occur. This can also be the cause of stronger depressing effect of grasses in the on-years of alternatively bearing trees, when the demand for nutrients is maximal (Figure 6).

Although the main effect of two times mowed grass on growth and yield of apples was negative, however the first and second order interactions show, that by combination with other factors e.g. use of effective herbicides, optimal nitrogen doses etc. the detrimental effect of such grass sward can be successfully eliminated. Besides, in intensive orchards on dwarf rootstocks with drip irrigation almost all apple roots grow in the tree strips. Consequently, one could consider the possibility to reduce the number of mowing the grass in alleyways of commercial orchards. Thus cold be considerably saved money, especially at a time, when the prices of fuel are rather high.

Surprising was the adverse effect of peat mulch on the trees. Mulching the soil in orchards is an ancient method, destined to improve soil physical properties, especially the water status, and also to prevent erosion. In the last decade interest in mulch has been augmented, but as a means of suppressing growth of weeds in the tree strips instead of herbicide use, which should be limited in connection with environmental considerations.

Various materials for soil mulching are used – sawdust, barley straw and even wool dust (Hartley et al., 1996), as well alfalfa straw, shredded office paper, black woven polypropylene (Neilsen et al., 2003).

Ideal mulch should detain evaporation of moisture from soil, but not hinder penetration of rain water, and should eliminate erosion; it should be also easily available and not too expensive. Such is coarse bark (Rifal et al., 2002) or shredded hardwood bark (Oliveira and Merwin, 2001; Yao et al., 2005). The latter mulch is reported to significantly increase soil P, Ca, cation exchange capacity, organic matter and soil pH.

The mulch must not contain weed seeds. Unfortunately, the peat used in our experiment was obtained from a low moor, therefore contained great amount of weed seeds. As the reason for the application of mulch was not controlling weeds, it was applied on the background of herbicide. Besides, the organic matter of the peat adsorbs simazine, and thus hinders its penetrating in the soil. As a consequence of both factors peat mulch, instead of controlling the weeds, promoted their growth and thus negatively influenced growth and yield of apple-trees, especially in plots with grassed alleyways. Their whole area was covered with undesirable vegetation that competed with the trees for water and nutrients.

Another question that should be answered by our investigation is whether simazine can improve the supply of nitrogen for fruit trees. Such view follows from investigations

of Raese (1977, 1991), and also from our previous experiment (Dimza et al., 2008), where the levels of simazine were 0 and 7.5 kg·ha^{-1} a.i. In these trial only the doses 5 and 10 kg·ha^{-1} a.i. were compared. However, the data of this trial also confirm the view of a positive influence of simazine on the availability of nitrogen (Figures 4 and 5). This relationship may be an argument in favour for the use of simazine. The main objection to use of simazine – concern about the possible pollution of fruits and thus danger to people's health – may be eliminated by the data about residues of simazine in fruits, which were negligible – near zero (Table 2).

Conclusions

Growing grasses in the alleyways, which were mowed only two times in a season slightly diminished the yield of apples and the vegetative growth of the trees. The peat mulch also had negative influence on growth and cropping of the trees. This negative effect was greatly overcome by nitrogen fertilizer. The detrimental effect of grasses was stated only in the on-years of alternative bearing apple trees.

Peat mulch had negative influence on growth and cropping of the trees. This was connected with adsorbtion and inactivation of simazine, consequently, with enhanced growth of weeds. The negative effect of peat mulch was less pronounced, when the soil in the alleyways was cultivated. A thin layer of mulch of mowed grass did not influence either the cropping, or growth of the trees. Simazine had improved the availability of nitrogen for fruit trees.

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Table 1. Main effects of the trial factors on the cropping and vegetative growth of 'Antonovka' apple trees and the amount of weeds in tree rows

Factors	The level of the factors	Rate of flowering, points (0 – 10), 1981 - 1985	Rate of cropping, points (0 – 10), 1982 - 1985	Yield, kg per tree, 1980 - 1985	Increase of trunk circumference, cm per year, 1981 - 1985	Rate of leaf green, points (0 – 10), 1982 - 1984	Amount of weeds, points (0 – 10), 1981 - 1985
Soil management in the alleyways	tillage	3.85	3.13	33.1	4.01	8.30	1.77
	growing grasses	3.46	2.47	23.3	3.82	8.10	1.73
Simazine doses	5 kg·ha^{-1} a.i.	3.67	2.74	28.2	3.88	7.91*	2.27**
	10 kg·ha^{-1} a.i.	3.64	2.86	28.2	3.95	8.49*	1.23**
Mulch in the strips	no mulch	3.69	2.90	29.2	4.00	8.35**	0.49
	grass mulch	3.68	2.93	29.6	3.99	8.67**	0.41
	the average of control and grass mulch	3.69	2.92***	29.4*	4.00**	8.51***	0.45***
	peat mulch	3.59	2.57***	25.8*	3.76**	7.58***	4.35***
Nitrogen doses	80 kg·ha^{-1} N	3.80	2.93	29.8	4.03	8.38***	1.93
	160 kg·ha^{-1} N	3.89	3.00	30.7	4.03	8.76***	2.14
	on the average of 80 and 160 kg·ha^{-1} N	3.85***	2.97***	30.3***	4.03***	8.57***	2.04***
	0 kg·ha^{-1} N	3.27***	2.47***	24.1***	3.68***	7.45***	1.18***

Table 2. Residues of simazine in apples of cultivar 'Antonovka' in 1986 dependent on the doses of simazine and application of mulches

Factor	Level of factor	Concentration of simazine, μg·kg^{-1}
Simazine	5 kg·ha^{-1} a.i.	2.6
	10 kg·ha^{-1} a.i.	3.0
Mulch	no mulch	2.2
	peat	0.8
	grass	3.1

DEVELOPMENT OF CROP ADAPTED SPRAY APPLICATION SYSTEM FOR ORCHARDS: PROJECT *ISAFRUIT*

Grzegorz DORUCHOWSKI [1], Ryszard HOLOWNICKI [1], Paolo BALSARI [2], Paolo MARUCCO [2], Jan van de ZANDE [3], Marcel WENNEKER [4]

[1] Research Institute of Pomology and Floriculture, Department of Agroengineering
Pomologiczna 18, 96-100 Skierniewice (Poland), e-mail: gdoru@insad.pl
[2] University of Turin - DEIAFA
Via Leonardo da Vinci 44, 10095 Grugliasco (Italy), e-mail: paolo.balsari@unito.it
[3] Plant Research International B.V. (WUR-PRI)
P.O. Box 16, 6700 AA Wageningen (the Netherlands), e-mail: jan.vandezande@wur.nl
[4] Applied Plant Research (WUR-PPO)
P.O. Box 200, 6670 AE Zetten (the Netherlands), e-mail: marcel.wenneker@wur.nl

Abstract

A Crop Adapted Spray Application system is being developed within the EC 6th FP project ISAFRUIT – "Increasing fruit consumption through a trans-disciplinary approach leading to high quality produce from environmentally safe, sustainable methods". The objective of the work is to ensure efficient and safe spray application in orchards according to actual needs and with respect to the environment. The system based on precision agriculture tools consists of three sub-systems: Crop Health Sensor (CHS), Crop Identification System (CIS) and Environmentally Dependent Application System (EDAS). The health status of apple trees is recognised by CHS based on spectral analysis of light reflected on the leaves. The system identifies the plant stress caused by apple scab infection in order to determine the specific place for spray application. The size and density of tree canopies is identified by CIS system using ultrasonic sensors which scan the tree row at three levels. Based on the information acquired by the sensors the system adjusts the spray volume according to the canopy width and density at corresponding tree levels. EDAS identifies environmental circumstances such as wind situation and sensitive areas neighbouring the orchard (surface water, melioration wells, public areas) and automatically adjusts spray quality and assisting air flow so that spray distribution is optimised and spray drift minimised in order to respect the local standards for buffer zones and protect the environment.

Key words: GPS navigation, precision spray application, spectral sensors, ultrasonic sensors

Introduction

In orchards, pesticides are usually applied regardless of the actual health status of protected crops, and with spray volume and airflow settings that ignore variable requirements of the target plants expressed in terms of their size and density. This is because conventional axial fan sprayers have no systems to identify plant health status and plant characteristics, and they are not equipped with devices to adjust critical spray application parameters such as spray volume, droplet size and airflow according to the actual need.

Plant protection, especially where pesticides are used very intensively as in fruit growing, should not have any negative impact on the environment especially in sensitive areas neighbouring the orchards such as surface water, melioration wells, sensitive crops

or public sites. These areas must not be contaminated by a spray drift (which is influenced by wind velocity, droplet size and airflow parameters). Conventional sprayers have no ability to alter the application parameters automatically according to the wind situation and proximity of sensitive areas.

The consumers' demand for healthy fruits, the growers' requirements for lower production costs and the environmental concerns of society stimulate research on low input plant protection techniques. Precision agricultural tools are needed to identify the problem and the target, as well as to recognise the environmental circumstances in order to apply pesticides according to the actual requirements at a precise rate and with respect to the environment. This is one of the objectives of the EU project within the 6th Framework Programme: "Increasing fruit consumption through a trans disciplinary approach leading to high quality produce from environmentally safe, sustainable methods – ISAFRUIT" (ISAFRUIT, 2006). Within this 4-year project launched in 2006, a Crop Adapted Spray Application system (CASA) is being developed by three partners: Research Institute of Pomology and Floriculture in Skierniewice (Poland), University of Turin in Grugliasco (Italy) and Wageningen University in Wageningen (The Netherlands). The objective of the CASA system is to adjust spray application parameters automatically according to the crop health status and crop characteristics, as well as the wind situation and sprayer position in the orchard. This is in order to reduce pesticide input and hence improve the quality and safety of fruit and environment. The preliminary results of the on-going development of the CASA system are presented in this paper.

Materials and Methods

The CASA system will consist of three sub-systems being elaborated independently by the project partners which will ultimately be integrated on a CASA sprayer model: (i) Crop Health Sensor (CHS) – determining crop health status to support decision making on spray application, as reported by Van de Zande et al. (2007); (ii) Crop Identification System (CIS) – identifying target characteristics for precision spray application, as reported by Balsari et al. (2007); (iii) Environmentally Dependent Application System (EDAS) – recognising the wind situation and position of the sprayer to protect sensitive areas in the orchard environment, as reported by Doruchowski et al. (2007).

To develop the CHS a novel technology has been used to quantify tree health conditions in the orchard. This technology is based on developments in crop sensing techniques for grassland and arable crop production, such as vision and spectral analysis (Schut, 2003). A measuring tool developed for characterising grass-swards has been adapted to measure single apple leaves picked in an orchard and placed on the floor underneath the sensor in the laboratory. The device consisting of two spectral cameras, measures the reflection in the band-widths 400-900 nm and 900-1600 nm.

In the preliminary series of experiments with this device, spectral analysis measurements were performed on individual apple leaves from different apple cultivars: 'Elstar', 'Jonagold', 'Rubens', 'Wellant' and 'Autento'. Both young and old leaves were measured on both the top and bottom sides. For the cultivars 'Elstar' and 'Jonagold', leaves infected with apple scab *(Venturia inaequalis)* and powdery mildew *(Podosphaera leucotricha)* were also measured.

In the second series of experiments, spectral analyses of individual leaves of two cultivars ('Gala', M9 rootstock) were taken to observe spectrum changes in time. Samples were compared for disparity between healthy and disease infected leaves (ascospores of apple scab) evaluated on 2 hours, 4 hours, 8 hours, 24 hours, 2 days, 14 days and 28 days after infection. The analyses of these spectral signatures are in progress.

The CIS is based on the ultrasonic sensors developed by DEIAFA and 3B6 company. With the CIS, the apple tree canopy width and density is determined based on the analysis of the echo of the ultrasonic signal emitted by the sensor. The frequency of the ultrasound used was 45 kHz, with the signal released by the sensor at a frequency of 10 Hz. The canopy width was calculated according to the formula: $W = R - 2 (x + d)$, where: W – canopy width; R – tree row spacing; x – constant distance from the sensor to sprayer axis; d – measured distance from the sensor to the canopy. The sensor-canopy distance was determined based on the time measured by the sensor, between signal transmission and receipt of the echo. The precision of distance measurement is less than 1% of the measured value; the detection range is up to 5 m. The tree canopy density was expressed as an index value, calculated based on the intensity and duration of the ultrasonic echo signal (Figure 1). The density index value was mainly correlated with the number of leaf layers in the tree canopy.

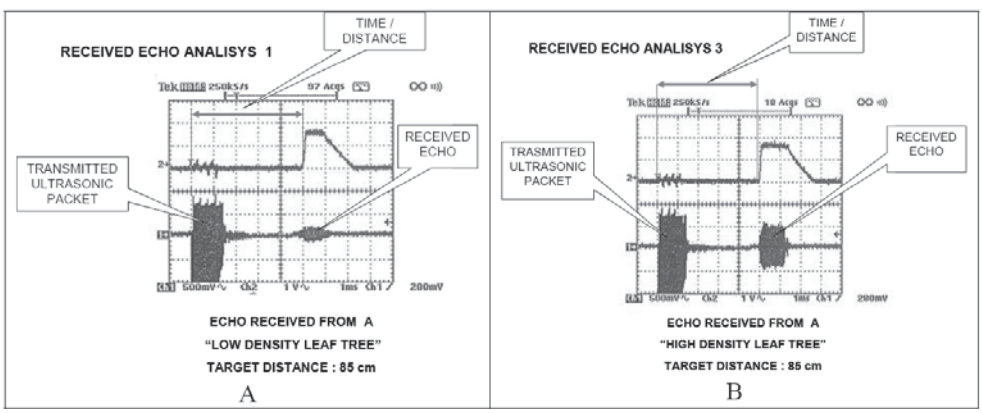

Figure 1. Ultrasonic signals transmitted and echoes received from tree canopies of different densities: A – low density canopy; B – high density canopy.

During the field experiments, the performance of ultrasonic sensors was tested in different aspects:

(a) assessment of repeatability of canopy width and density records acquired by one sensor, for different sprayer passes at travel velocity 6 $km \cdot h^{-1}$
(b) effect of travel velocity (2, 4, 6 and 8 $km \cdot h^{-1}$) on vegetation profile acquired by one sensor
(c) interference between 3 active sensors (travel velocity 6 $km \cdot h^{-1}$)

The experiments were carried out in an apple orchard of 'Golden Delicious', with 4 m trees, spaced 4.5 x 1.5 m. The sensors scanned a 70 m tree row. In tests (a) and (b), a single sensor passed the trees at a height of 2.0 m above ground level. In test (c),

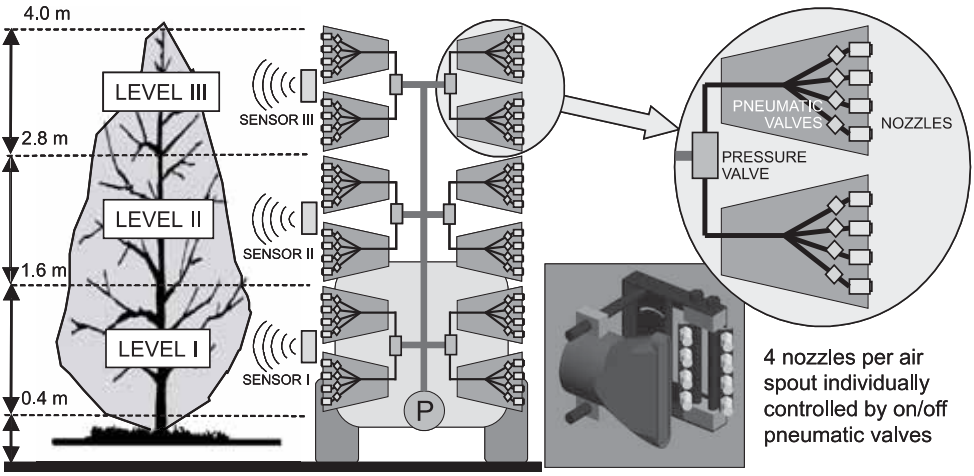

Figure 2. Ultrasonic sensors and spray application system of CIS sprayer.

3 sensors were mounted above each other at 1.0 m, 2.0 m and 3.0 m above ground level to record the canopy profile at three levels simultaneously (Figure 2).

Data acquired by the sensors are processed by a control unit, the purpose of which is to control real time application of variable spray volumes related to the measured canopy width and density at 3 levels. For this purpose, a special spray application system was developed and mounted on a Hardi Arrow sprayer with a double rotor radial fan P540D (19 000 m^3/h). The airflow produced by the fan is ducted to 12 individually adjusted air spouts (6 at each side of sprayer) mounted on a vertical tower support. Each spout is equipped with a set of 4 nozzles, individually controlled by pneumatic on/off valves. The volume of spray to be applied towards a given level of the canopy (according to its width and density) can be adjusted by opening the appropriate number of nozzles. Thus, each of the 3 canopy levels are measured by the sensors and addressed by two air spots and 8 nozzles. Field trials with the CIS controlled spray application system will be carried out in spring 2008.

EDAS is a spray application system for orchards which identifies environmental circumstances and adjusts application parameters accordingly, so that spray distribution is optimised and spray loss is minimised. This protects sensitive areas neighbouring the orchards. The environmental circumstances to be identified are: wind velocity and direction measured with a ultrasonic anemometer (Vaisala WINDCAP® Ultrasonic Wins Sensor WMT50), and orchard boundary and sensitive areas such as surface water, melioration wells, buildings, sensitive crops, public sites, etc. from GIS. According to the wind situation and sprayer position relative to the orchard boundary/sensitive areas (GIS/GPS), the spray quality automatically adjusted by altering the nozzles (fine spray/ coarse spray) in order to minimise the spray drift. In addition, appropriate nozzles closed to respect the local standards for buffer zones. Furthermore, in order to minimise the emission of spray towards sensitive areas, and yet ensure the best possible spray distribution in the orchard, the supporting air jet adjusted individually for left and right section of the sprayer by manipulation of airflow on the inlet and outlet of the fan.

The EDAS sprayer was designed and a novel air jet adjustment system was constructed and assembled on a Hardi Arrow sprayer with a double rotor radial fan P540D (19 000 m^3/h). Initially, an air collector for distribution of airflow to 16 individual air spouts (8 for each section of sprayer) was elaborated and fixed to the fan. Having obtained the uniform air distribution from the collector, an adjustable air vane was assembled inside it to adjust or close the airflow individually to the left and right sections of the sprayer (Figure 3 A). The simultaneous measurements of air velocity from the 8 air spouts were made with a set of hot film anemometers and an 8-channel data logger in stationary, dynamic and orchard situations. In each scenario, closing the airflow on one section resulted in an increase in air velocity on the other section by 30-40%. In order to avoid this, a diaphragm leaf shutter was designed and fixed on the fan inlet (Figure 3 B). Once the collector vane closes the airflow to one section, the leaf shutter restricts the flow of air sucked in by the fan accordingly. Therefore, the air velocity remains constant when one section is closed.

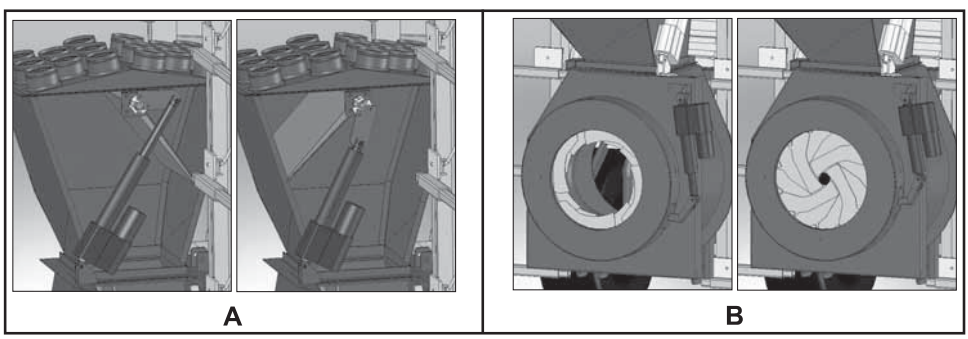

Figure 3. Airflow adjustment system on EDAS sprayer:
(A) air vane in the air collector (position V1 and V11);
(B) diaphragm leaf shutter on the inlet of radial fan (position S4 and S0).

The measurements of air velocity, as described above, were repeated for all possible combinations of:

- 11 positions of air vane in the air collector (V1 ... V11)
  where:
  V1 = airflow closed to the right section and fully open to the left section,
  V6 = central position – equal distribution of airflow to both sections.
  V11 = airflow closed to the left section and fully open to the right section.
- 6 positions of the leaf shutter (S0 ... S5)
  where:
  S0 = leaf shutter closed,
  S5 = leaf shutter fully open.

The measurements were made 30 cm from the outlet of the air spouts: in 5 replications for each combination, simultaneously for 8 spouts, separately for left and right section (in total: 5 280 measurements).

Double nozzle holders with fine spray and coarse spray nozzles controlled individually by on/off pneumatic valves, were assembled at the air spouts. The valves

alter the nozzles (fine spray/coarse spray) depending on the wind situation and position of the sprayer in relation to the orchard boundary and the sensitive areas. Control unit and software is being elaborated to control both air and spray emission systems in various situations and to integrate them with GPS. The field test of EDAS sprayer will be carried out in spring 2008.

Results and Discussion

CHS: First results showed a difference in reflection between infected leaves and healthy leaves. The most evident differences in spectral signatures were observed for the wavelengths: 690, 820, 880, 1400 and 1550 nm (Figure 4). These wavelengths may be used to discriminate between healthy and infected leaves to support decision on suspending or triggering the spray application.

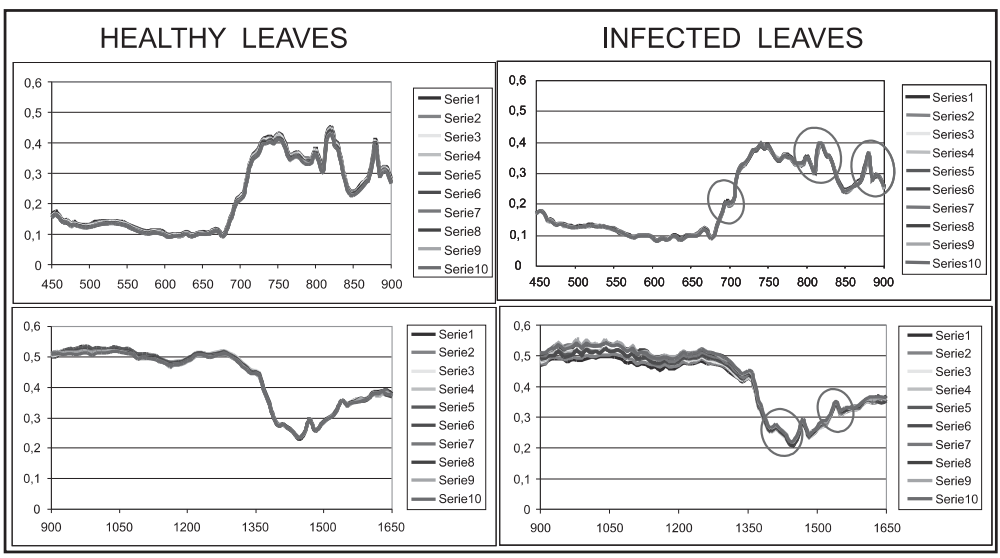

Figure 4. Spectral signatures of healthy and apple scab infected apple leaves ('Elstar') with marked points of difference.

Based on the data obtained, the development of the crop health sensor will start by identification of discriminate wavelengths for water stress, nutrient stress and cultivars. Having done this a CHS dedicated sensor will be developed. The CHS can then be integrated in CASA system, working together with the CIS and the EDAS sub-systems.

By adapting the sensors for fruit production, dose and timing of chemicals can be determined based on the crop health situation of the fruit tree. Health status maps of the orchard can be made based on the continuous measuring of plant health during spraying by means of the CHS, and using the position of the sprayer (GPS) during the season. Spray volume can be adapted following the relationship between crop health and required protection level using a specific plant protection product.

CIS: The results of canopy width and density, measured by the ultrasonic sensor in three replications, gave fairly similar vegetation profile (Figure 5). At the travel velocity

6 km/h and ultrasonic signal transmission frequency 10 Hz, the measurements were taken with a resolution of 10 cm of the driving distance. The observed differences in width and density measurements between the replications were mainly due to the difficulty of repeating exactly the same path in the field with this resolution. Analysis of the differences between the maximum and minimum values recorded for each sampling point in the three replications showed that for 80% of the points, the discrepancies in canopy width remained within 0.40 m and in canopy density index within 300 units. It has been assumed that for real time spray volume control during spray applications, sufficient accuracy will be obtained based on an average value of sensor measurements taken over 1 m of the tree row length.

Forward speed did not significantly affect the repeatability of the vegetation profile acquired by the sensor, either regarding canopy width (Figure 6) or canopy density. For 80% of sampling points the canopy width discrepancies ranged within 0.25 m, and for canopy density index remained within 250 units.

Comparing the vegetation profile obtained by the single sensor at the height 2.0 m above ground and the middle sensor (at the same height) out of three sensors scanning the three tree row levels, it has been observed that the top and the bottom sensors did not interfere with the middle one (Figure 7).

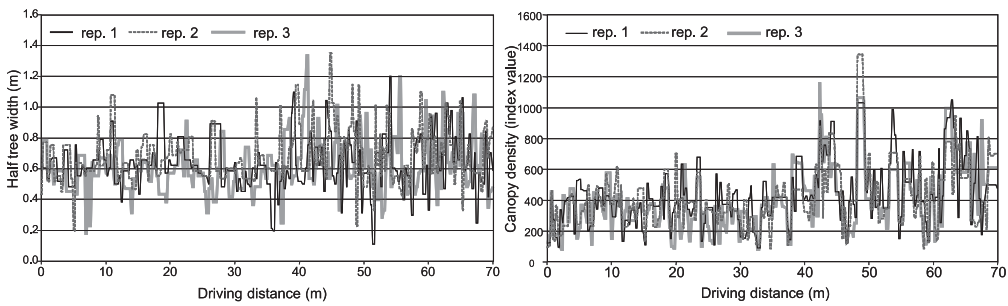

Figure 5. Canopy width and density profile recorded by ultrasonic sensor at canopy level II, during three runs (6 km·h^{-1}) over 70 m row of apple trees.

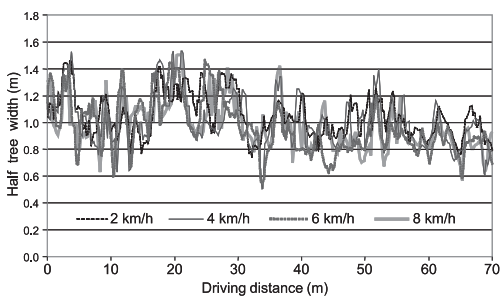

Figure 6. Canopy width profile recorded by ultrasonic sensor at canopy level II, during runs over 70 m row of apple trees at different travel velocities.

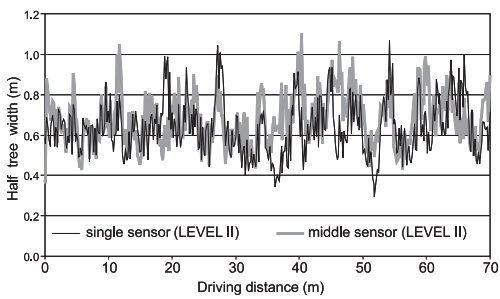

Figure 7. Canopy width profile recorded at canopy level II by single ultrasonic sensor and by the middle sensor only with top and bottom sensors both active, during runs over 70 m row of apple trees at travel velocity 6 km·h^{-1}.

The obtained results showed that simple and relatively cheap ultrasonic sensors provide reliable data on tree canopy width and density, which may be used for real time control of spray volume adjustment according to the target characteristics. In this sense they are superior to more sophisticated and costly sensors, such as LIDAR (Walklate et al., 1997), which are used in post-processing applications.

EDAS: The results of air velocity measurements showed that by the manipulation of the diaphragm leaf shutter on the fan inlet and air vane in the air collector of EDAS sprayer, it was possible to adjust air velocity individually for each section. With the shutter/vane setting being S2/V6 as a reference (average airflow velocity LEFT/RIGHT section = 14.0/15.6 $m \cdot s^{-1}$) the combinations of shutter and vane positions were identified to obtain air velocities on LEFT/RIGHT air spout section fairly corresponding with the required ones in various typical situations (expressed in percentage deviation from reference air velocity values) (Figure 8), e.g.:

- S0/V1 (+29%/-100%) or S0/V11 (-100%/+12%) – when spraying the boundary row,
- S0/V2 (+13%/-68%) or S0/V10 (-64%/+2%) – when spraying the last but one row,
- S1/V4 (-4%/-25%) or S1/V9 (-36%/+1%) – when spraying the last but two row,
- S3/V3 (+32%/-23%) or S3/V9 (-16%/+20%)– to counteract a cross wind ≥ 2 $m \cdot s^{-1}$.

The reference setting S2/V6 with a symmetrical airflow distribution is to be used inside the orchard (from the third row on), during longitudinal winds and cross winds < 2 $m \cdot s^{-1}$.

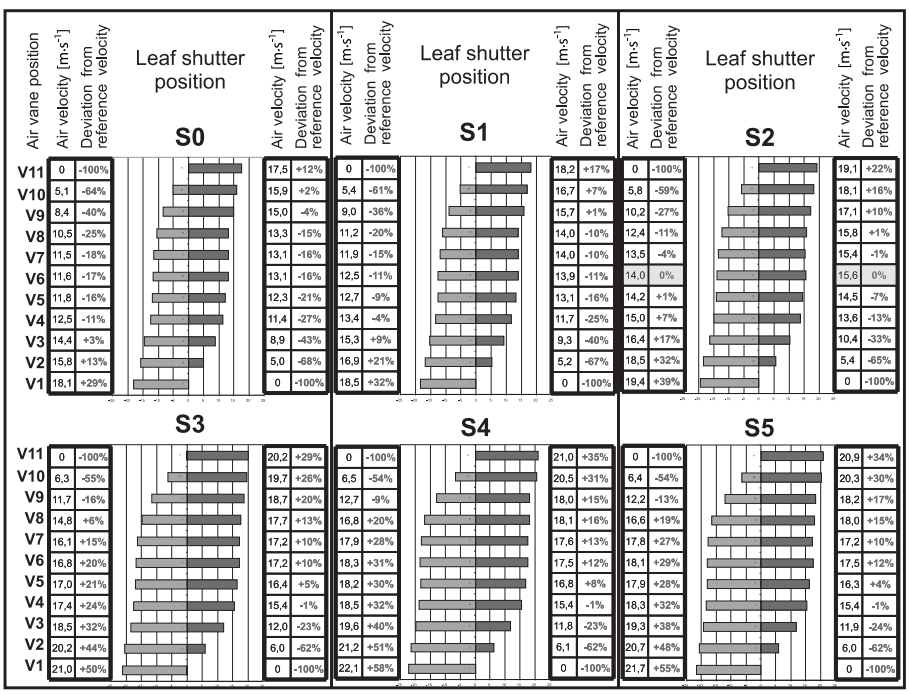

Figure 8. Average airflow velocities ($m \cdot s^{-1}$) measured for LEFT and RIGHT air spout sections and air velocity deviations (%) from the reference setting (S2/V6) for different positions of diaphragm leaf shutter on the fan inlet and air vane in the air collector of EDAS sprayer model. Each average value was calculated from velocities measured at 8 air spouts in 5 replications.

During spray application, the shutter/vane settings are adjusted automatically according to the position of the sprayer in the orchard (GIS/GPS) and wind velocity/ direction measured with the ultrasonic anemometer mounted on the sprayer. The airflow might also be adjusted based on the canopy width and foliage density measured by the ultrasonic sensors of CIS system to support the spray application concept proposed by Salyani (2007).

Conclusions

The CASA system, consisting of CHS, CIS and EDAS sub-systems, at the described stage of development, shows the potential to recognise plant stress due to disease infection on apple leaves and identify the basic target characteristics such as tree canopy width and foliage density. The acquired information, when processed in real time can be used by the CIS sprayer model to perform on-the-go adjustment of the spray volume applied on the fruit trees and hence facilitate precise, crop adapted spray application in orchards.

The EDAS sprayer model equipped with wind sensor and GPS navigation system enables real time adjustment of application parameters such as airflow and spray quality to reduce the negative environmental impact of spray applications in orchards. It is going to be integrated with the CHS and CIS sub-systems to meet the objectives of the CASA system to the full extent.

Future work within the ISAFRUIT project will focus on finalising the development of software to control all the processes performed by the CASA system, and carrying out field experiments to evaluate the obtained effects in terms of application quality, biological efficacy and reduction of environmental pollution.

Acknowledgements

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EFFECT OF SOME CULTURAL PRACTICES ON GROWTH AND YIELD OF CRANBERRY (*VACCINIUM MACROCARPON* AIT.): PRELIMINARY STUDY

Danuta KRZEWINSKA, Bozenna BORKOWSKA, Waldemar TREDER, Anna TRYNGIEL-GAC

Research Institute of Pomology & Floriculture,
Pomologiczna Street 18; 96-100 Skierniewice, Poland
e-mail: Danuta.Krzewinska@insad.pl

Abstract

In field trials in Central Poland some cultural practice and mycorrhizal inoculation were evaluated for vegetative growth and yield of cranberry (*Vaccinium macrocarpon* Ait.) cv. 'Pilgrim'. The experiment was set up in autumn of 2004 and is still conducted. Plots were established at two soil treatment: one on mineral soil with low organic matter content (adjustment soil pH_{KCl} to 4.0) and the other with additional organic matter (peat). Before planting one half of plants were inoculated with ericoid mycorrhizal fungi and the others – not. Also fertilizer trials were conducted at rates of 0, 20 and 40 kg·N $ha^{-1}yr^{-1}$ on permanent plots. There were twelve treatments total. The plantation was irrigated with acidified water (pH 4.0-4.5)There were significant treatment effects for vegetative growth. Adding organic matter increased vegetative growth, in case of non mycorrhized plants; but not effected when mycorrhizal fungi were applied. In two years fruiting period there were not significant effects of soil, mycorrhizal inoculation and the rate of nitrogen on yield or mean fruit weight. Generally, the highest rate of nitrogen decreased yielding.

Key words: cranberry, mineral nutrition, mycorrhizal fungi, organic matter, soil

Introduction

American cranberry (*Vaccinium macrocarpon* Ait.) is the only wild berry species cultivated commercially. European native wild species of *Vaccinium* (*Vaccinium oxycocus*, *V. myrtillus* L., *V. vitis-idaea* L., *V. uliginosum* L.) are not commercialized as a crop (Pliszka and Clayton-Greene, 1993). Fruit of *Vaccinium* species have high capacity for absorbing oxygen free radicals (Heimhuber and Herrmann, 1990) and have become recognized as one of the most health food (Mainland and Tucker, 2002). Cranberries have a host of health benefits because of a high content vitamins A and C, flavonoids, organic acids and other substances (Karczmarczyk and Zbiec, 1998).

Vaccinium plants need acid soil (pH_{KCl} 3.5-4.0), sufficient soil moisture and aeration in upper soil level, with high organic matter content (Haffner, 1993). Cranberry is acidophilous and prefer ammonium nitrogen (Claussen and Lenz, 1999). Roots have symbiotic associations with mycelium of mycorrhizal fungi. Symbiosis between *Vaccinium* plants and fungi increased nitrogen and phosphorus absorption, (Myers and Leake, 1996), tolerance to stress and pathogenic microorganisms (Koron et al., 2000).

In North America improvement of management practice, and marketing have made cranberries one of the area's top agricultural crops (Stang *et al*., 1993). In Poland

there is the potential for more rapid expansion in producing these plants but they need more attention and experiments.

The aim of the study was to modify cranberry site to effectively production of high quality fruits in Polish climatic and soil conditions.

Materials and methods

The experiment was conducted on sandy soil with pH_{KCl} 4.0 status and low organic matter content (1.3%). Plantation was drip irrigated with acidic water (H_2SO_4).

Shoot cuttings of cranberry cultivar 'Pilgrim' were propagated in greenhouse of Research Institute of Pomology & Floriculture, Skierniewice. Plants were grown in pots and one year rooted cuttings were planted in the field. One half of plants were inoculated with ericoid mycorrhizal fungi (ERM). The inoculum was prepared in Polish Laboratory MYKOFLOR and was applied to the roots as a water suspension of fungi filaments before planting.

The plants were planted in autumn 2004, in the split-plot design, with 4 replications. Main plots there were nitrogen fertilization (0 – none (N 0); 20 kg·ha^{-1} (N 20); 40 kg·ha^{-1} (N 40), and subplots there were mycorrhizal and organic matter treatment (total: 12 treatments). One plot: 12 plants, at distance 0.50 x 0.25 m; i.e. 1.5 m^2.

Treatments:

- Mineral soil – plants were not inoculated ERM (Soil –M and N 0 or N 20 or N 40)
- Mineral soil – plants were not inoculated ERM + organic matter (Soil+peat-M and N 0 or N 20 or N 40)
- Mineral soil – plants inoculated ERM (Soil+M and N 0 or N 20 or N 40)
- Mineral soil – plants inoculated ERM + organic matter (Soil+peat+M and N 0 or N 20 or N 40)

In rows with additional organic matter there were dug furrows and mix (soil and peat in 3:1 proportion) was added.

Vegetative growth was measured as follow: in two first years - number and total length of annual horizontal shoot (runners) – all runners over 10 cm of length; from the third year density of vines covering soil surface was estimated.

Other measurements:

- time of flowering
- total number of uprights
- total number of flowering uprights
- yielding – kg·plot^{-1}
- crop quality – in 2006: weight of fruits; in 2007 fruit coloring and no commercial crop (small, rotted, damaged fruits)
- photochemical activity of photosynthesis – was be assessed with number of parameters received from MINI-PAM fluorometer. This method uses a chlorophyll fluorescence measuring system (Genty et. al., 1989) and measures the electron transport rate (ETR) at light saturation.

Data were analyzed by STATISTICA 7.0 software package, Duncan's test, at $P = 0.05$.

Results

Vegetative growth. No mycorrhized cranberries planted on soil with additional organic matter showed very good vegetative growth. In 2005 and 2006 number of runners and their total length were higher when peat was applied and plants were not mycorrhized before planting. In case of mycorrhized plants they grew stronger in sites without peat (Figure 1). In the first year of the study high dose of nitrogen (N 40) increased vegetative growth more than in 2006 (Figure 2). In 2005 we observed longer runners in mycorrhized plants than in non mycorrhized, especially lower doses of nitrogen (N 0 and N 20) (Figure 3). In 2006 similar effect was observed in sites with peat, but when organic matter was not added mean length of one runner was the highest in treatment without mycorrhization and nitrogen fertilization (N 0).

In 2007 we observed low dense mats across the plot where high dose of nitrogen was applied (N 40), independent of soil:mycorrhiza combination, the least effective was in treatment: soil+peat+ERM N 40. The most effective covering was when plants were mycorrhized and nitrogen was not applied (N 0), in both soil treatments (data not presented).

Flowering and number of uprights. Cranberry plants flowered as clusters of 2-6 blossoms from end of the May to the first days of July both in 2006 and 2007, on short, vertical branches. Total number of upright and flowering stems was similar in all treatments (data not presented).

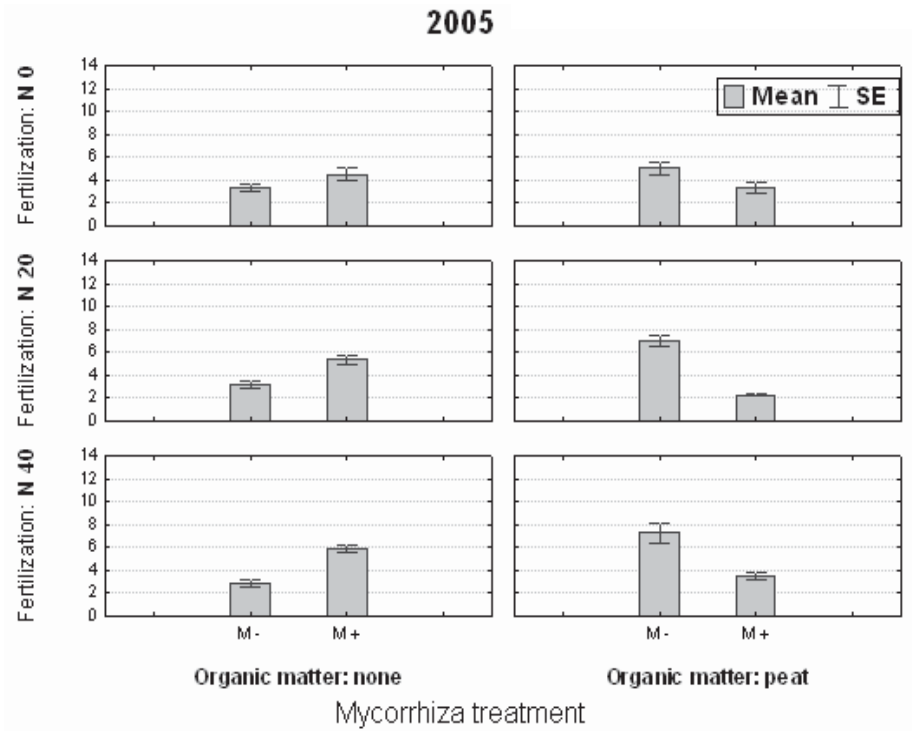
Yielding. In both years of cropping no mycorrhized plants produced higher yield than mycorrhized plants, with exceptions: in sites without peat and the highest dose of nitrogen (N 40), also, in treatment with additional organic matter and the lowest dose of nitrogen (N 0). In most cases, peat supported cranberry yields – yield was higher, than from plants growing in mineral soil. High dose of nitrogen mostly were associated with decreased yield (Figure 4).

Crop quality. In 2006 mean fruit weight varied from 1.29 g to 1.40 g. Non mycorrhized plants gave bigger fruits when mix: soil-peat was applied and a little smaller when grew in soil without peat (Table 1). In 2007 fruits were bigger than in 2006 and mean fruit weight was more diverse than in 2006: from 1.32 g to 1.82 g. In general, we observed bigger fruits from plants which gave smaller fruits in 2006.

In 2007 we checked fruit coloring and percentage of non commercial yield. Fruits were well-colored (over 90% fruits with red blush over 70% of their surface) with one exception: when peat and the highest dose of nitrogen was applied (64% of well-colored fruits). In general, the percentage of no commercial crop was higher when high doses of nitrogen and mycorrhization were applied (data not presented).

Photosynthetic activity. Chlorophyll a fluorescence method has been used to assess cranberry response to mycorrhization and fertilization with different doses of nitrogen when plants were growing in mineral soil, amended with peat. Mycorrhization increased value of ETR, showing for improvement of light processes of photosynthesis. Non mycorrhized plants, fertilized with nitrogen (N 20) grown in soil and fertilized with N 40 but amended with peat showed the highest ETR value.

In 2006 ETR for mycorrhized plants was similar for N 20 and N 40 nitrogen dose and for both soil treatments (Table 2).



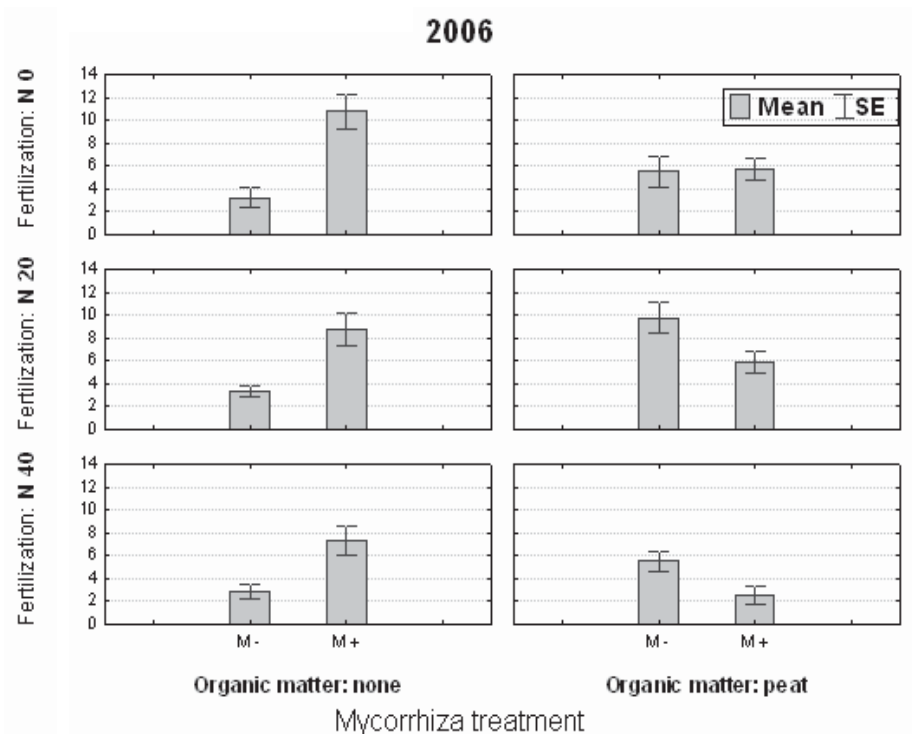
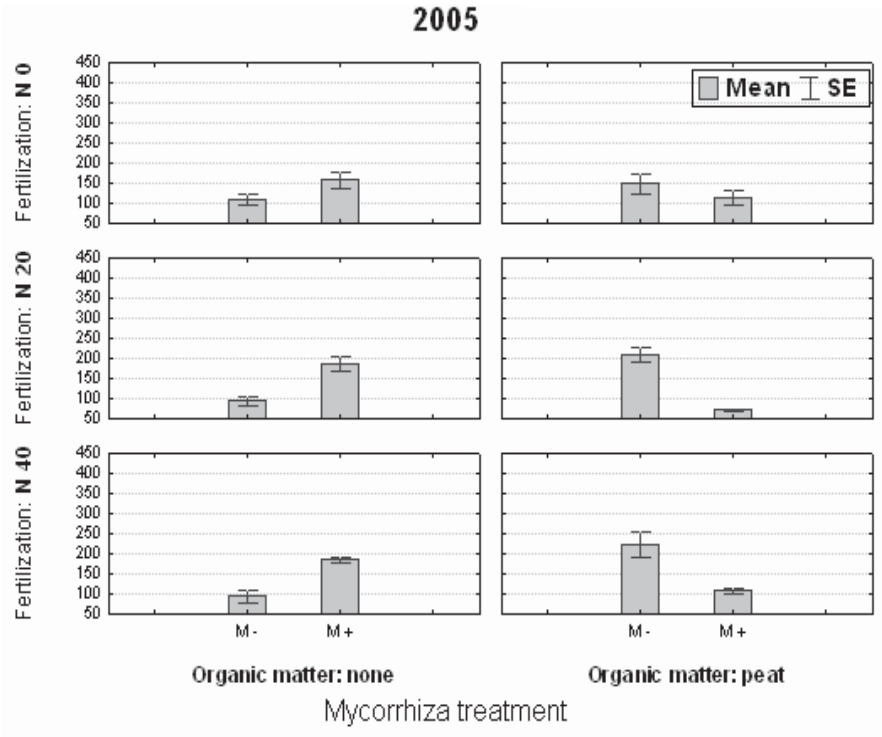


Figure 1. Number of annual shoots (runners) per one plant



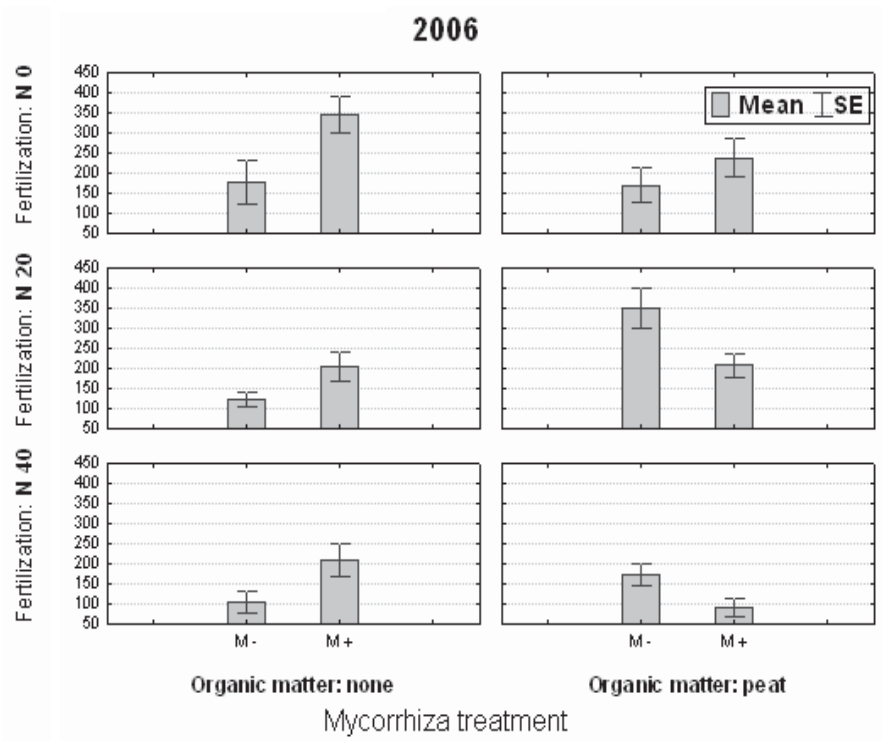


Figure 2. Total length of runners per one plant [cm]

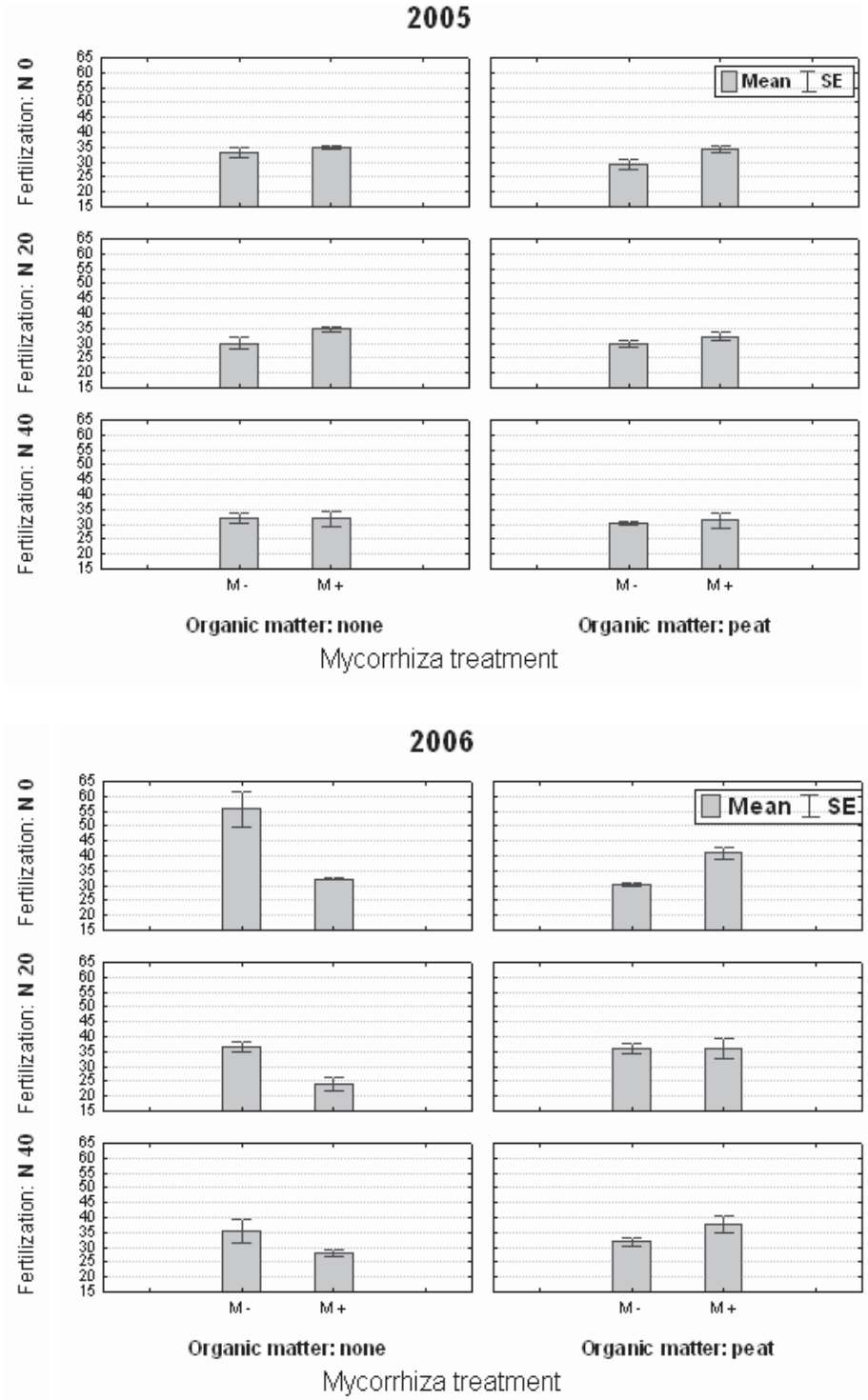
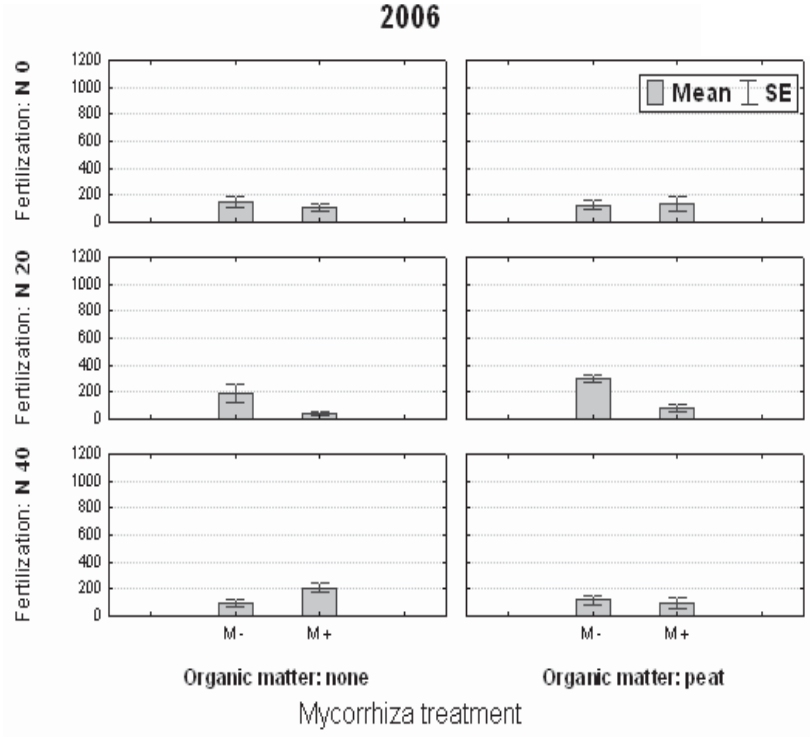


Figure 3. Mean length of one annual shoot [cm]



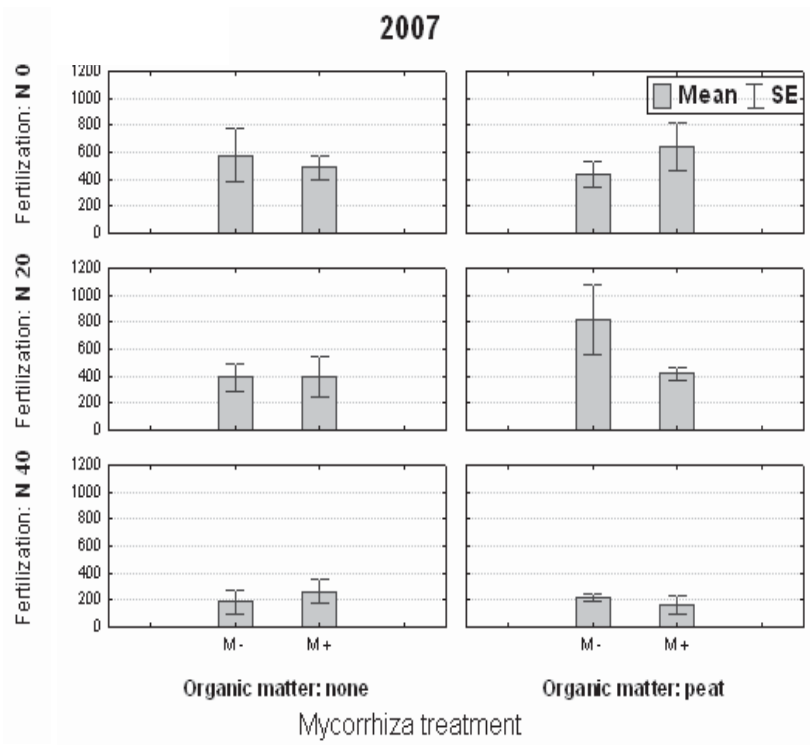


Figure 4. Yielding [kg·plot^{-1}]

Discussion

Commercial cranberry production increases all over the world, and could also increase in Poland. The goal is to get intensive vegetative growth (the numerous runners to cover the soil surface) in two first years after planting. Then, production of strong upright plants becomes very important. In this study, good vegetative growth was obtained in first year, and from 2006 we observed that some plants were died, especially when high dose of nitrogen were applied. Site requirements are poorly described for cranberry in Poland. Our previous experiments (Krzewinska and Smolarz, not published) showed similar effect, i.e. very good vegetative growth and yielding in the first years and then plants were died more and more, from year to year.

Many experiments showed that cranberry needs specific sites with high organic matter content. In our experiment plants grown in soil amended with peat grew more vigorously than in pure soil. It is known, that organic matter promotes pore space, which improves soil aeration and provides a good environment for root penetration and uniform distribution. Also, organic matter is converted to plant-available ammonium-N. In general limiting nitrogen use to rate that avoids excessive growth and runner production (Davenport and Patten, 2002). When N fertilization was done carefully it promoted the growth of berry production while minimizing vine growth.

Environmental factors and inputs of N fertilizer affect the effectiveness of the cranberry-mycorrhiza interaction. Inoculation of mycorrhizal fungi (ERM) increased vegetative growth when there no additional organic matter and decreased them when peat was applied.

On organic soils plants can tolerate over supply of N applications but on the other fields can reduce yielding and fruit quality, also expense of fruit production (Davenport, 1997). In this experiment mean fruit weight was decreased when the highest dose of nitrogen was applied, also there were more fruits classified as 'no commercial' fruits.

The amount of red color (anthocyanin content) in fruits is the major factor determining cranberry crop value, harvesting is timed to achieve the maximum red color (Eck, 1990). Fruit red color intensity is one of the mayor quality characteristics for cranberries, because of that 92-95% of cranberry crop is processed and good color is needed for making high quality processed products. In general, in the study fruits were well colored, independent of treatment.

We will check root colonization of plants at the end of the study. Root colonization by ERM increased with age of plantation (Scagel, 2003). May be in our young plantation there is low mycorrhizal status.

Conclusions

- Soil management affects the effectiveness of the cranberry-mycorrhiza interaction.
- Adding organic matter to mineral soil promotes vegetative growth more than mycorrhization.
- Nitrogen fertilization is necessary to sustain production but high rate (N 40) is no required.
- High dose of nitrogen (N 40) influences negatively yielding

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Table 1. Mean mass of 100 fruits [g]

Treatment	2006			2007		
	0 N	20 N	40 N	0 N	20 N	40 N
Soil - M	129.6 a	130.0 ab	136.8 cd	153.4 c	181.9 e	139.0 ab
Soil + peat - M	137.3 cd	138,5 d	139.6 d	137.3 a	141.2 ab	157.3 c
Soil + M	130.9 ab	136.8 cd	137.3 cd	143.1 b	140.9 ab	132.1 a
Soil + peat + M	129.4 a	132.7 abc	135.1 bcd	172.2 d	154.7 bc	140.8 ab

*Different letters in the same year columns indicate significant difference [P = 0.05]

Table 2. Photosynthetic activity – ETR parameter values of chlorophyll fluorescence (2006)

Treatment	N 0	N 20	N 40
Soil – M	17,9	25,2	20,0
Soil + Peat – M	17,5	21,7	27,0
Mean	**17,7**	**23,5**	**23,5**

Treatment	N 0	N 20	N 40
Soil + M	24,2	29,9	31,4
Soil + peat + M	27,6	30,0	32,7
Mean	**25,9**	**30,0**	**32.0**

THE INFLUENCE OF NPK FERTILIZERS ON THE DEVELOPMENT OF OLIGONITROPHYLS IN ALLUVIAL SOILS

Marijana PEŠAKOVIĆ[1], Dragutin ĐUKIĆ[2], Leka MANDIĆ[2], Rade MILETIĆ[1], Milan RAKIĆEVIĆ[1]

[1]Fruit Research Institute Čačak, Kralja Petra I 9, 32000 Čačak, Serbia
e-mail: marijanap@tfc.kg.ac.yu
[2]University of Kragujevac, Faculty of Agronomy Čačak,
Cara Dušana 34, 32000 Čačak, Serbia
e-mail: lekamg@tfc.kg.ac.yu

Abstract

Over 2003 – 2005, a study was performed on the influence of different rates of NPK fertilizer on oligonitrophyls pressure in alluvial soil of a plum orchard. The trial was set up in the experimental plum orchard established by Fruit Research Institute Čačak, as well as at the laboratory of Department of Microbiology, Faculty of Agronomy Čačak. The soil was treated with 400 – 1,000 kg ha^{-1} of 8:16:24 + 3 % of MgO mineral fertilizer. Unfertilized soil served as the control. The effect of the studied mineral fertilizer was determined three times over the growing season, oligonitrophyls pressure being checked by indirect rarefaction method on Fyodorov's nutritive me dium. The application of high fertilizer rates brought about decrease in oligonitrophyls pressure. Of all studied variants, the one with highest nitrogen rate (variant N_4) exhibited the strongest inhibitory effect. On the other hand, fertilizer rates enhanced the number of oligonitrophyls. The influence of the fertilizer was highest at the third sampling. Furthermore, the effect was highest in 2003. The application of 600 kg ha^{-1} of mineral fertilizer gave highest plum yield.

Key words: Oligonitrophyls, NPK fertilizing, plum orchard.

Introduction

Fertilization is one of the most significant cultural practices in modern plant production. Nitrogen is required for normal growth of a great number of plants. Even in soils richest in organic matter its content does not exceed 4% (Đukić et al., 2007). Nitrogen fertilizer functions as a supplement to the existing organic matter in soil, controlling thus mineral content rate as well as the number and activity of soil microorganisms. It also contributes to tree productivity. On the other hand, overactivation of soil microorganisms may come out damaging, as these processes result in the loss of organic matter in soil, weakening of its physical, chemical and biological properties, and serious ecological violation. This primarily refers to the increased presence of easily driven forms of nitrate nitrogen, which pollutes the surface and underground waters (Đukić et al., 2006), and the accumulation of nitrates in plants above the allowed level (Govedarica et al., 1991) – not only of those used in human diet but for cattle feed as well (Marinković and Grčić, 1993). Excessive nitrate nitrogen content provides transformation thereof into nitrates and nitrozamines which can cause cancer (Hoffman, 1986).

Rational and effective application of mineral fertilizers, nitrogen in particular, presupposes delicate approach to this issue whereby microbiological investigations

ought to be particularly focused on. Being the most important soil component, microorganisms are major indicators of soil fertility (Milošević et al., 2004).

The objective of our investigations was to examine the effect of different mineral fertilizer rates on the number of oligonitrophyls required in soil for high plum production.

Materials and methods

The investigations were performed over 2003 – 2005 in a plum orchard of Fruit Research Institute Čačak as well as at the Department of Microbiology, Faculty of Agronomy, Čačak. Mineral fertilizer NPK 8:16:24 + 3 % MgO, product of "Zorka" Sabac, was applied in autumn 2002 at the following rates (kg ha^{-1}): 400 (variant N_1); 600 (variant N_2); 800 (variant N_3) and 1000 (variant N_4); The soil untreated with the stated nutritives served as the control. In the ensuing two years, residual effects of applied fertilization were tested, and the plum orchard was not subsequently fertilized.

The trial field was 68 m^2 large, planted with plum cv Čačanska Lepotica in random block design, in three replications. The soil was alluvial, of slightly acid reaction (pH value in 1nKCl = 5.9), moderately supplied with organic matter (2.65% humus) and well supplied with plant-available P and K (AL-method: mg 100 g^{-1} of soil = 15.0 P_2O_5 and 20.4 K_2O).

Regular cultural practices were applied over the growing period. All cultural practices, i.e. fertilization, pruning, summer pruning, interrow practices, protection from diseases and pests, etc. were applied over the period of training system formation. Soil samples intended for microbiological analyses were collected in three replications during growing seasons (on May 11, Sept. 17, Nov.11), over the three-year period. The number of oligonitrophyls was being determined by indirect dilution method on Fyodorov's nutritive medium.

Climate characteristics of the studied region are presented in Table 1.

Field, laboratory and mathematical/statistical methods of scientific research were used in the paper. The obtained results were subjected to the variance analysis, whereas LSD test was used for determining the significance of differences.

Results

Statistical analysis of the obtained trial results on the influence of applied fertilizer (A), period of sampling (B) and year of investigaton (C) suggests that, statistically, A and B had marked effect on the development of olygonytrophyls in soil (Table 2). Cummulative effect of C and B (interaction B x C) was statistically very significant.

The results shown in Table 2 infer that high rates of mineral fertilizers had inhabitory effect on the number of oligonitrophyls in soil. N_4 variant (4.407 x 10^5) had notable inhibitory effect on the development of oligonitrophyls. In contrast, lower fertilizer rates were stimulating regarding the very issue, particularly N_2 variant (15.840 x 10^5). The number of oligonitrophyls was greater over the second period of sampling (13.615 x 10^5) and over 2003 (9.007 x 10^5) .

The data on the average plum yield (t/ha) are shown in Table 3.

Discussion

Low and medium fertilizer rates applied in the planting stimulated the development of olygonytrophyls in soil. Govedarica et al. (1991) reached a similar conclusion suggesting the stimulating effect of lower nitrogen rates and lumbrihumus on the number of oligonitrophyls in untreated rows, whereas on treated areas these had a negative effect. Larger number of microorganisms in soil and increased activity thereof induced by incorporation of a mineral fertilizer reaches its maximum up to the level at which rearrangement of previously activated microbial community is prevented (Mandić, 2001). Incorporating higher fertilizer rates (800 and 1000 kg/ha) enhances the inhibitory effect. This results in the violation of established biological soil balance as well as in the development of non-specific toxic microorganisms (Pešaković et al., 2008), which in the very case affected the development of oligonitrophyls under respective conditions.

The greatest number of oligonitrophyls was reported over the second sampling. As the character of fertilizer activity on the development of microorganisms is directly dependent on cummulative effect of different ecological factors (moisture and temperature of soil, level of cultivation of soil, and grown plant species (Barabasz et al., 2002)), the results arising from the experiment had been anticipated. The second sampling (Sept. 17) was characterized by more regular distribution of rainfall and temperatures (Pešaković, 2007), which resulted in higher number of the microorganisms over this period. The number of oligonitrophyls was markedly more significant over the second period of sampling compared to the third period of sampling (Table 2). Contrasting the influence of the applied fertilizers by periods of sampling suggests that the increase in fertilizer rate brings about decline in number of the monitored microorganism group. The strongest inhibitory effect was observed in N_4 variants over all stated periods, nevertheless their significance remains within the range of statistically insignificant to statistically significant. Similar was reported for N_3 variants. Lower rates of fertilizer dressings resulted in greater number of olygonitorphyls in soil over all stated periods. However, it was only in N_2 variant, over the first and the second sampling (12.706×10^5 and 25.926×10^5 respectively) that highly significant change in number of oligonitorphyls was observed. Over the second sampling, N_1 variant brought about major increase in number of this microorganism species, i.e. (17.073×10^5).

The number of oligonitrophyls was higher in the first year of study (2003). Drought and excessive heat were evidenced over the growing season in 2003. For example, over the seven-month period (May – November), precipitation rate was by one third lower than the long-term mean (LTM). In addition, air-temperature was by 2.9oC higher (Table 1). The remaining two years were slightly warmer, and, regarding precipitation rate, it was approximate to LTM. Over the entire period of study, the number of this microorganism species was constant (Table 2) whereby high nitrogen rates exhibited the strongest inhibitory effect. However, strong inhibitory effect had high significance only in 2003 and 2004, i.e. 5.740 x 105 and 4.610 x 105 respectively. Over the entire period of study, application of lower fertilizer rates was stimulating as regards the number of these microorganisms, particularly in N2 variant (17.338 x 105, 13.725 x 105 and 11.388 x 105, respectively). In contrast to the stated, the stimulating effect in N1 variants was

statistically insignificant (Table 2).

The highest plum yield (21.946 t/ha) was obtained with incorporation of 600 kg/ha of the fertilizer.

The research results pointed to a somewhat lower-than-expected plum yield, one of the reasons probably being flower frosting (Rakićević et al., 2004; 2005) as well as reduced soil biological productivity induced by high mineral fertilizer rates.

The obtained plum yields as well as chemical and biological properties of soil and economic/ environmental indicators suggest that the application of 600 kg/ha fertilizer is recommended in plum growing under the stated agro-environmental conditions.

Conclusions

The results of the investigation of the effect of the application of mineral fertilizers on the number of oligonitrophyls in soil in a plum orchard infer the following:

- the number of the studied group of microorganisms depended on fertilizer rate, period of sampling and year of study;
- high fertilizer rates caused the decline in the number of oligonitrophyls;
- the highest inhibitory effect was reported in the variant with highest nitrogen application;
- the application of lower and medium fertilizer rates resulted in greater number of oligonitrophyls;
- the most stimulating effect was reported in the variant where moderate nitrogen rates were applied;
- the effect of fertilizer applicaton was most pronounced over the second period of sampling;
- the number of oligonitrophyls was greater in the first year of study (2003);
- the most significant rise in plum yield was obtained where 600kg/ha mineral fertilizer were applied.

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Table 1. Weather characteristics (Čačak Weather Bureau) and long-terms means (LTM)

The period		Precipitation rate and mean air-temperatures in Čačak*							Total	Mean
		May	June	July	Aug.	Sept.	Oct.	Nov.		
2003	mm	62	51	69	6	34	77	27	326	
	°C	19.8	25.1	24.2	26.4	17.3	10.2	8.9		18.8
2004	mm	66	121	82	58	35	27	98	487	
	°C	16	21.7	23.5	22.8	18.1	14.3	6.2		17.5
2005	mm	72	84	100	66	91	23	83	519	
	°C	17.2	21	23.7	20.3	18.2	11.8	5.2		16.8
LTM (1965-1994)	mm	89	98	76	60	56	48	59	486	
	°C	16.2	19.5	20.9	20.5	16.9	11.8	5.8		15.9

* About 5 km as the crow flies (eastward from the trial field).

Table 2. Average number of olygonitrophyls in soil (10^5/1.0 g of fully dry soil) depending on applied fertilizers (A), period of sampling (B) and year of investigaton (C) in plum orchard planted with cv 'Čačanska Lepotica'

Fertilizer (A)				N_1	N_2	N_3	N_4	Control	$\overline{X}$
Year (C)	2003	Period (B)	I	12.000	17.670	8.890	6.110	10.330	11.000
			II	16.447	21.333	4.890	4.443	10.220	11.467
			III	5.220	5.777	3.777	3.110	4.890	4.555
		$\overline{X}$		11.222	14.927	5.852	4.554	8.480	9.007
	2004	Period (B)	I	7.003	9.557	2.777	1.557	3.887	4.956
			II	19.443	34.777	8.440	7.113	13.890	16.733
			III	6.110	9.110	4.223	1.890	5.000	5.267
		$\overline{X}$		10.852	17.814	5.147	3.520	7.592	8.985
	2005	Period (B)	I	8.887	10.890	6.220	5.110	7.110	7.643
			II	15.330	21.667	8.113	6.667	11.447	12.645
			III	7.943	11.780	3.650	3.663	4.607	6.329
	$\overline{X}$			10.720	14.779	5.994	5.147	7.721	8.872
$\overline{X}$			I	9.297	12.706	5.962	4.259	7.109	7.866
			II	17.073	25.926	7.148	6.074	11.852	13.615
			III	6.424	8.889	3.883	2.888	4.832	5.383
$\overline{X}$				10.931	15.840	5.664	4.407	7.931	8.955
lsd									
lsd	A			B	C	AxB	AxC	BxC	AxBxC
0.05	2.622			2.031	2.031	4.542	4.542	3.518	7.867
0.01	3.474			2.691	2.691	6.017	6.017	4.660	10.421

Table 3. The average yield of plum cv Čačanska Lepotica (t/ha) depending on the applied fertilizer

Fertilization variant	Yield (t/ha)			$\overline{X}$
	2003	2004	2005	
N_1	33.332	18.212	7.392	19.646
N_2	40.862	16.714	8.261	21.946
N_3	36.546	17.416	8.401	20.787
N_4	33.382	20.716	7.135	20.411
Ø	23.453	17.172	4.566	15.064
$\overline{X}$	33.515	18.046	7.151	19.571

SUITABILITY OF THE NEW POLISH BLACKCURRANT CULTIVARS FOR MECHANICAL FRUIT HARVESTING

Stanislaw PLUTA, Edward ŻURAWICZ

Fruit Plant Breeding Department Research Institute of Pomology and Floriculture
96-100 Skierniewice, Pomologiczna 18, Poland
e-mail: spluta@insad.pl; Edward.Zurawicz@insad.pl

Abstract

Results of the suitability of new Polish blackcurrant cultivars for fruit picking by the harvester ("KPS-4b") are presented in the paper. The studied cultivars were 'Tisel', 'Tiben', 'Ores', 'Ruben' and 'Tines' released at the Research Institute of Pomology and Floriculture (RIPF) in Skierniewice, Poland. As standard cultivars were used 'Ben Lomond', 'Ben Connan', 'Ojebyn' and 'Titania'. Two field experiments were established at the Experimental Orchard at Dabrowice, near Skierniewice, Central Poland in autumn of 1998 and 2002. Studies and observation were carried out in 2000-2007. Results showed that the standard cultivar Titania and new Polish cultivars 'Tiben' and 'Tisel' produce the biggest bushes. Other tested cultivars produced small or medium-size plants. The earliest in fruit ripening were 'Tisel', 'Tines' and 'Ojebyn' the next earliest were 'Titania' and 'Ben Connan'. The remaining cultivars 'Ben Lomond', 'Ores', 'Ruben' and 'Tiben' could be classified as mid-late ripened. The new Polish cultivars ('Tisel', 'Tiben' and 'Ruben') produced considerably higher yields than all standard cultivars. The largest fruits were produced on 'Ruben', 'Tines' and 'Ores'. 'Tisel', 'Ben Lomond', 'Ben Connan' and 'Titania' produced medium sized berries, and – 'Tiben' and 'Ojebyn' produced the smallest. The quantity of fruit collected by the harvester ("KPS-4b") in 2007 ranged from 88,3 to94,6%. The smallest amount of damage of shoots and bushes during machine harvesting were observed for the 'Ojebyn', 'Ben Lomond', 'Ben Connan' and 'Ores' varieties followed by 'Ruben' and 'Tines' and the highest amount of damage was noted in 'Titania', 'Tiben' and Tisel'. The most resistant to main fungal diseases were plants of 'Tisel', 'Tines', 'Ruben', 'Ores', 'Titania' and 'Ben Connan'. The most susceptible varieties were 'Ben Lomond' and 'Ojebyn'.

Key words: blackcurrant, *Ribes nigrum* L., new cultivars, mechanical fruit harvest, yield

Introduction

Blackcurrants are an important economic crop within the category of small fruits grown commercially on plantations and home gardens and by amateurs. For many years, Poland has been the world's largest producer and exporter of this fruit. The annual production in the last several years has ranged from 100,000 to 140.000 tones (GUS, FAO, Rynek Owoców i Warzyw, 2007). The interest in cultivation of blackcurrants has grown in concert with advent of new cultivars, highlighting the technology of plant cultivation on commercial plantations as well as the use of harvesters for fruit picking.

In Poland, the production of the blackcurrants is actually conducted with modern methods. Almost all the fruit comes from good plantations, where they are collected by different harvesters. Through the analysis of the development of blackcurrant cultivation in our country, the dramatic change of its economic contribution becomes obvious. Highly profitable years are alternated and tempered with years of lower economic yield. It is understandable, then, that growers seek technologies of cultivation, which

will decrease production costs. Modern and more efficient cultivars are an important element of this progress in cultivation. Such cultivars should be productive and their fruits suitable for the many different types of markets. The most important qualities are consistently high yields, high quality fruits, berries that are conducive for processing and freezing and the resistance to the main pests and diseases (Broniarek-Niemiec et al., 2000; Pluta and Markowski, 2001; Markowski and Pluta, 2002). These cultivars should also lend themselves to mechanical harvesting (Salamon, 1993).

Since 1986 the applied breeding program of the blackcurrant has been carried out at the Fruit Plant Breeding Department of the Research Institute of Pomology and Floriculture (RIPF) in Skierniewice, Poland (Pluta and Zurawicz, 1993; Zurawicz et al., 2000; Pluta 2001). The breeding program has culminated with the release of five cultivars 'Tiben', 'Tisel', 'Ores', 'Ruben' and 'Tines' (Pluta and Zurawicz, 2002; Pluta 2003; Pluta and Zurawicz, 2006). They are now included in the Polish National List of Fruit Plant Varieties and Plant Breeding Rights (PBR) of the Research Centre for Cultivar Testing (COBORU) in Słupia Wielka. Moreover, these cultivars have received the PBR protection on the territory of Canada till 2025 and European Union till 2030. The new Polish as well as other foreign cultivars are examined for production value in the Polish climate, soil conditions, and machine harvesting traits (Salamon, 1993; Pluta and Broniarek-Niemiec, 2000; Pluta and Markowski, 2001; Gwozdecki et al., 2002, Broniarek-Niemiec and Pluta, 2003).

The aim of the studies was to evaluate an usefulness of the new blackcurrant cultivars ('Tiben', 'Tisel', 'Ores', 'Ruben' and 'Tines') for commercial cultivation employing the use of mechanical harvesters.

Materials and Methods

Observations and studies were carried out in two separate experiments located on fields of the Experimental Orchard (SD) in Dabrowice near Skierniewice, Central Poland. The first experiment was established in the autumn of 1998. Three new cultivars ('Tiben', 'Tisel' and 'Tines') were the subject of the research. As standard (control) cultivars 'Ben Connan', 'Ben Lomond' and 'Titania' were included. Examinations and observation were conducted in seven consecutive years (2000-2006). The second experiment was established in the autumn of 2002 and involved the five new cultivars ('Tiben', 'Tisel', 'Ores', 'Ruben' and 'Tines') bred at the RIPF in Skierniewice. The tested cultivars were compared with the control cultivars, 'Ojebyn' and 'Titania', which are still planted on commercial plantations in Poland. The yield results obtained for first three years (2005-2007) are listed herein.. Both experiments were designed according to the same arrangement of the random block plan in four replications. The plot was consisted of 50 bushes, planted at the density of 3.80 x 0.50 m (5.000 bushes/ha). Bushes of each cultivar have been grown in separate (neighboring) rows of the lengths of over 200 m.

In both experiments, date of ripening (harvesting), yield and size (weight) of the fruits were evaluated. The size of bushes [m^2] was assessed on the basis of the measurements of the height and the width of the plants (perpendicularly to the row). Also damage to the plants caused by the mechanical harvester was recorded. In the second experiment losses of fruit yield (left on bushes and dropped to the ground) and

the efficacy of harvest by the self-propelled ("KPS-4b") were also evaluated in the studies. In both experiments, the resistance of plants to the fungal diseases: American powdery mildew (*Sphaerotheca mors-uvae* Berk.), leaf spot (*Drepanopeziza ribis* Kelb.) and white pine blister rust (*Cronartium ribicola* Fish) was evaluated in the first half of July and in the second half of August using a ranking scale of 1-5 (Karolczak et al., 1973), where 1 equals no symptoms, 3 – medium symptoms, 5 – very severe symptoms.

Results and Discussion

The blackcurrant cultivars tested in experiment I differed in economical traits. The selected results of observations are presented in tables 1 and 2. The dates of fruit ripening and yields of six genotypes in 2000-2006 are included in table 1 (below).

The earliest fruits ripened on bushes of the new Polish cultivars 'Tisel' and 'Tines' and the standard cultivar 'Titania'. The standard cultivars 'Ben Lomond' and 'Tiben' were the latest. The third standard cultivar 'Ben Connan', as compared to this group of cultivars, had a medium date of fruit ripening (Table 1).

Analysis of the results of fruit yield showed that, on average in seven years of investigations (2000-2006), 'Tiben' produced the highest yield (9.9 t/ha), followed by 'Tisel' (8,4 t/ha) and 'Tines' (8.0 t/ha) (Table 1). The standard cultivar 'Titania' had lowest yield (6.2 t/ha). 'Ben Connan' and 'Ben Lomond' were medium producers yielding appropriately 7.3 and 7.0 t/ha. In that experiment, the special attention should be given to 'Tiben'. This cultivar's yields exceeded 'Ben Connan' and 'Ben Lomand' by 35-40% and as much as 60% more than 'Titania'. The cultivar 'Tisel' was very productive and 'Tines' was productive.

These cultivars also differed in fruit size measured by the mass of 100 berries chosen randomly. The Polish cultivar 'Tines' produced the largest fruits with the mass of 100 fruits equaling 135.3 g. The remaining cultivars were characterized by medium fruit mass (size) ranging from 101.3 to 112.4 g (Table 1).

The size of bushes (height x width) of the examined blackcurrant cultivars was also assessed (table 2). It is an important morphological feature of plants, which determines the efficacy of mechanical harvesting and the degree of the shoots' damage by the harvester (Salamon, 1993; Salamon and Cianciara, 1994).

The size of the bushes [m^2] was variable and depended on genotype. On average, the standard cultivar 'Titania' and the new cultivars 'Tiben', 'Tisel' and 'Tines' produced the biggest bushes and. The average bush sizes ranged from 1.68 to 1.98 m^2. The two remaining standard cultivars of the "Ben" series ('Ben Connan' and 'Ben Lomond') had considerably smaller bushes than the genotypes mentioned above (Table 2).

An assessment of damage to bushes (annual and frame shoots) conducted after mechanical harvesting by the harvester ("KPS-4b"), showed that 'Ben Lomond' had the least damaged shoots, followed by 'Ben Connan', 'Tines' and 'Tiben'. The most damaged shoots were observed on bushes of the cultivars 'Tisel' and 'Titania'.

Tested blackcurrant genotypes also demonstrated different field resistance to the main fungal diseases (Table 2). Only the Scottish standard cultivar 'Ben Lomond' was very susceptible to American powdery mildew (4.0 in the ranking scale 1-5). The remaining tested cultivars were resistant to this pathogen. All genotypes were susceptible to leaf

spot on to different degrees. The least susceptible to this fungus were Polish cultivars 'Tisel' (1.4) and 'Tines' (1.7) as well as the standard cultivar 'Ben Connan' (1.8). The infection of plants by white pine blister rust also varied. The standard cultivars 'Titania' and 'Tisel' were resistant to this pathogen. The remaining examined genotypes showed low or medium level of susceptibility to this disease in field conditions.

Results concerning dates of fruit ripening, production value, weight, size of bushes and efficacy of mechanical harvesting of the blackcurrant cultivars evaluated in the experiment II are presented in tables 3 and 4. These are the preliminary results of investigation and observation done in three consecutive years (2005-2007) and concern the third, fourth and fifth years of the cultivation of bushes on the experimental plantation.

In this experiment, examined blackcurrant cultivars differed in the date of fruit ripening (harvest). Similar to experiment I, the earliest fruits ripened on bushes of 'Tisel'; it was at the end of the first half of July. In the next stage (3-5 days later) the fruits of the standard cultivars 'Ojebyn' and 'Titania' and the new cultivar 'Tines' ripened. Fruits of the remaining cultivars, 'Ores', 'Ruben', and 'Tiben' ripened the latest among the tested genotypes at 3-7 days later than those of the last group.

The blackcurrant cultivars varied considerably in the amount of yield (Table 3). New Polish cultivars 'Ruben', 'Tiben' and 'Tisel' produced much higher yields than the standard cultivars 'Ojebyn' and 'Titania'. The average yields for the three years of investigation of the new cultivars ranged from 5.6 to 7.3 t/ha, and standard cultivars yielded only 3.9 and 4.5 t/ha. This was 20 to 55% higher yields than 'Titania' and as much as 44 to 87% higher than 'Ojebyn'. The two remaining new cultivars, 'Ores' and 'Tines' yielded less fruit (4.1 t/ha) as compared with the standard cultivars. The poorer yielding of 'Tines' (particularly in 2007) was caused by the hard spring frost damage to the buds and flowers. It is obvious, that in 2007, fruit yield of all the tested cultivars was lower than in normal years, when no spring frost occur during flowering.

Fruit size of the investigated cultivars varied considerably depending on the genotype and the year of study (Table 3). The average mass of 100 berries for all genotypes ranged from 95.5 and 149.5 g. The biggest fruits were collected from 'Tines' and 'Ruben' (appropriately, 145.8 and 149.5 g). 'Ores' produced somewhat smaller fruits (130.5 g). The mass of 100 fruits of the standard cultivar 'Titania' and the new cultivar 'Tisel' reached about 121 g. 'Tiben' produced the smallest fruits produced (108.1 g) and the second smallest were produced by the standard cultivar 'Ojebyn' (95,3g.).

In experiment II 5-year-old plants of the tested genotypes produced different size bushes [m^2] as measured by the height x width of plants (Table 3). The new cultivar 'Tiben' and the standard cultivar 'Titania' boasted the biggest bushes. The average bush sizes for both cultivars were 1.74 m^2 and 1/68 m^2, respectively. Other investigated cultivars produced considerably smaller bushes than those above mentioned genotypes. On average, the size of the bushes of the five cultivars ranged from 1.20 m^2 and 1.36 m^2.

The results of the efficacy of harvesting from the test bushes of blackcurrant cultivars grown on the experimental plantation are presented in Table 4. The plants are still young (5-year-old), so these results are preliminary and studies will be continued for next 2-3 years.

The highest efficacy of mechanical harvesting with the harvester "KPS-4b" was obtained for the new cultivars 'Tisel' (94.5%) and 'Tiben' (93.7%) which produced high yields (55.3 and 51.0 kg/plot, respectively). Losses of fruits uncollected from bushes and dropped off during harvesting by the machine were relatively low. The efficacy of fruit harvesting for the standard cultivar 'Titania' was 92.6%, which produced considerably low yields (39.3 kg·plot^{-1}) while at the same time the lowest losses of uncollected fruits were noted. For the cultivar 'Ojebyn', the efficacy was 91.3%, with medium fruit yield (44.8 the kg·plot^{-1}) and medium losses of fruits left on bushes and dropped on soil. Similar efficacy of 90.6% was produced by 'Ores', in which mechanically harvested yields were high (51.0 kg·plot^{-1}, but losses of the fruit yield was on the medium level. The lowest efficacy of mechanical harvesting was recorded for the new cultivar 'Ruben' (88.4%), which produced the highest yield (56.5 kg·plot^{-1}) but also suffered from the highest losses of fruits uncollected by the machine from the bushes and dropped to the ground. The same was basically true for 'Tines' (88.3%), which had really low fruit yield (23.8 the kg·plot^{-1}), but losses of fruits were relatively low (Table 4).

Blackcurrant genotypes were characterized by different levels of plants' resistance to the economically detrimental fungal diseases; American powdery mildew, leaf spot and white pine blister pine. Average results of the evaluation for 2006-2007 in field conditions are presented in Table 5.

All tested blackcurrant cultivars showed very high resistance to American powdery mildew and no typical symptoms were observed on plants. (Table 5). They were more or less susceptible to leaf spot. The least amount of symptoms were recorded on leaves of the cultivar 'Tiben' (2.0 in the ranking scale 1-5). The following cultivars 'Ores'; 'Ruben' and 'Tisel' demonstrated a medium level of susceptibility to this pathogen (2.7-2.9). The most infected by *D. ribis* were 'Tines'(3.4) and the standard cultivars: 'Titania' (3.5) and 'Ojebyn' (3.7). The susceptibility of plants to white pine blister rust was relatively low. No symptoms of this disease were observed on leaves of the new Polish cultivars: 'Tisel', 'Ores' and 'Ruben' as well as the standard cultivar 'Titania'. A small infection by this pathogen was noted on the leaves of 'Tiben' (only 1.2 in the ranking scale 1-5) and 'Tines' (1.8). Plants of the standard cultivar 'Ojebyn' were the most susceptible (2.7).

Conclusions

1. High productivity of blackcurrant cultivars determines the profitability for growers. The new Polish cultivars 'Tisel', 'Tiben' and 'Ruben' demonstrated their high yields in both field experiments.
2. All tested genotypes differed in fruit size (mass). The largest fruits were produced on the new cultivars 'Tines', 'Ruben' and 'Ores'. Other cultivars had medium-sized or small fruits.
3. The new Polish cultivars demonstrated good suitability for mechanical harvesting by the harvester ("KPS-4b") with regards to the efficacy of fruit harvest and machine damage to the shoots during harvesting. They equal the standard cultivars 'Ojebyn', 'Ben Lomond' and 'Ben Connan', but exceed 'Titania'.
4. Plants of all new cultivars are the most resistant to the main fungal diseases. Cultivation of theses cultivars (permits to limit the plant protection "I don't know

what is being said here"), reduce costs of production and provide lower risks of contaminating the natural environment and fruits with residues of pesticides, in accordance with current requirements of the European Union.

5. The breeding program of blackcurrants conducted at the RIPF in Skierniewice, Poland has resulted in new valuable cultivars. Planting of theses cultivars on commercial plantations could influence the optimization of fruit production of blackcurrants in Poland and fortify our position in world.

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Table 1. The results of ripening, yield and weight of the mechanically harvested fruits of the new Polish blackcurrant cultivars in experiment I established in 1998, Experimental Station at Dabrowice, 2000-2006.

Cultivar	Average time of fruit harvest	Fruit yield [t/ha]								Average mass of 100 berries 2000-2006 [g]
		Average 2000 -2001 /x	2002	2003	2004	2005	2006	Total 2002-2006	Average	
1. *Titania*	*10.07*	*1.6*	*4.2*	*7.1*	*8.1*	*10.3*	*6.0*	*35.7*	***6.2***	*109.3*
2. *Ben Connan*	*13.07*	*2.3*	*8.8*	*13.9*	*5.7*	*7.8*	*5.1*	*41.3*	***7.3***	*108.6*
3. *Ben Lomond*	*17.08*	*1.0*	*4.9*	*12.1*	*7.5*	*7.3*	*9.0*	*40.8*	***7.0***	*109.9*
4. Tisel	07.07	1.2	6.7	13.6	8.9	12.8	7.3	49.3	**8.4**	112.4
5. Tines	10.07	1.7	5.5	10.8	6.8	14.7	8.6	46.4	**8.0**	135.3
6. Tiben	17.08	3.7	8.8	12.4	11	14.1	9.5	55.8	**9.9**	101.3

Explanations:

/x – 2000-2001 – hand harvested fruits,
2002-2006 – machine harvested ("KPS-4b") fruits.

Table 2. The bush size and field resistance of the blackcurrant cultivars evaluated in the experiment I established in 1998 for mechanical harvesting, Experimental Station at Dabrowice, 2000-2006.

Cultivar	Average bush size /x 2000-2006 [m^2]	Susceptibility to fungal diseases (average for 2002-2006) [ranking scale 1-5] *		
		Powdery mildew	Leaf spot	White pine blister rust
1. *Titania*	*1.69*	*1.0*	*2.3*	*1.0*
2. *Ben Connan*	*1.03*	*1.0*	*1.8*	*2.1*
3. *Ben Lomond*	*1.18*	*4.0*	*2.1*	*2.3*
4. Tisel	1.78	1.0	1.4	1.0
5. Tines	1.68	1.0	1.7	2.0
6. Tiben	1.98	1.0	2.3	1.7

Explanations:

/x – Bush size [m^2] as measured by the height x width of bushes
* – ranking scale 1-5, 1 – no symptoms, 3- medium symptoms, 5 – very severe symptoms

Table 3. The date of fruit ripening, yield and average mass of fruits and bush size of the new Polish blackcurrant cultivars evaluated in experiment II established in 2002, Experimental Station at Dabrowice, 2005-2007

Cultivar	Average time of fruit harvest 2005-2007	Fruit field [t/ha]					Average mass of 100 berries [g]	Average bush size [m²]
		2005 *	2006	2007	Total	Average	2005-2007	2005-2007
1. Ojebyn	*10.07*	*3.9*	*3.4*	*4.5*	*11.7*	***3.9***	*95.5*	*1.32*
2. Titania	12.07	*5.1*	*5.1*	*3.9*	*14.2*	***4.7***	*120.7*	*1.68*
3. Tisel	7.07	8.3	8.0	5.5	21.8	**7.3**	120.9	1.36
4. Tines	10.07	4.1	6.0	2.4	12.4	**4.1**	145.8	1.20
5. Ores	15.07	3.7	3.6	5.1	12.3	**4.1**	130.5	1.21
6. Ruben	15.07	4.9	7.3	5.6	17.8	**5.9**	149.5	1.24
7. Tiben	17.07	7.8	7.3	5.1	20.2	**6.7**	108.1	1.74

Explanations:

* – 2005 – hand harvesdted

2006-2007 – machine harvested by harvester ("KPS-4b")

Table 4. The yield of mechanically harvested fruit and the losses of fruits (left on bushes and dropped on soil) and an efficacy of mechanically harvested fruit in 2007, Experimental Station at Dąbrowice, 2007.

Cultivar	Average fruit yield picked by harvester [kg/plot]	Fruit left on plants and dropped /x [kg]		Losses of fruit yield /y		Efficacy of mechanically harvested WZ [%] **
		5 bushes	soil	[kg/bush]	[kg/ha]	
1. *Ojebyn*	*44.8*	*0.83*	*0.71*	*0.078*	*390*	*91.3*
2. *Titania*	*39.3*	*0.34*	*0.78*	*0.058*	*290*	*92.6*
3. Tisel	55.3	0.45	0.75	0.060	300	94.5
4. Tines	23.8	0.50	0.61	0.056	280	88.3
5. Ores	51.0	1.10	0.81	0.096	480	90.6
6. Ruben	56.5	1.20	1.41	0.130	650	88.4
7. Tiben	51.0	0.43	0.82	0.064	320	93.7

Explanations:

/x – fruits were collected from the bush and from soil on 5 bushes randomly chosen in each replication, immediately after mechanical harvesting.

/y – total weight of fruits collected from bushes and soil

** – efficacy of mechanical harvesting (WZ) calculated as the quotient of fruit yield picked by harvester and sum of fruits collected from bushes and soil after mechanical harvesting , according to formula:

$$WZ\ (\%) = \frac{\sum PO}{\sum PK + PZ} \times 100\%$$

where:

PO – sum of fruit yield picked by harvester,

PK – sum of fruit weight picked by hand from bushes after mechanical harvesting,

PZ – sum of fruit weight collected by hand from soil under bushes after mechanical harvesting.

Table 5. The field resistance of plants of the blackcurrant cultivars evaluated in experiment II for machine harvested fruits, Experimental Station at Dabrowice, 2006-2007

Cultivar	Susceptibility to fungal diseases (average for 2006-2007) [ranking scale 1-5] *		
	Powdery mildew	Leaf spot	White pine blister rust
1. *Ojebyn*	*1.0*	*3.7*	*2.7*
2. *Titania*	*1.0*	*2.5*	*1.0*
3. Tisel	1.0	2.9	1.0
4. Tines	1.0	3.4	1.8
5. Ores	1.0	2.7	1.0
6. Ruben	1.0	2.9	1.0
7. Tiben	1.0	2.0	1.2

Explanations:

* – ranking scale 1-5, 1 – no symptoms, 3- medium symptoms, 5 – very severe symptoms

POMOSAT – DESIGN AND IMPLEMENTATION OF SUSTAINABLE ORCHARD MANAGEMENT

Florin STĂNICĂ, M. DUMITRAŞCU, Adrian PETICILĂ

Research Center for Integrated Fruit Growing Faculty of Horticulture
University of Agronomic Sciences and Veterinary Medicine
B-dul Mărăşti, nr 59, 011464, Bucureşti, Romania
e-mail: flstanica@yahoo.co.uk

Abstract

The impact of climate changes on the environment and, implicitly, on the fruit tree agro ecosystem is a complex topic. The aim of POMOSAT project is to investigate the potential impact of climate changes on fruit tree species development and growth, and the impact of the diseases and pests affecting these cultures, using regional climate numeric models, impact models and satellite monitoring techniques. Creating a complex database of climate records, satellite images, field and laboratory observations and measurements, it can be developed a sustainable fruit farm management system. The main objectives of the project are related to mapping the studied fruit tree agro-systems, using satellite techniques; to create a space database (GIS) for the studied zones; to characterize the test zone climate evolution, using agricultural climate factor types specific to fruit trees; to analyze the fruit tree plantations vegetation status, using conventional methods and satellite techniques; to monitor the pathogenic agents and populations of useful organisms within the studied fruit tree zones; to predict the potential impact of climate changes upon fruit tree plantations by numeric simulations; to establish a model between climate evolution and sustainable fruit farm management; to create an interactive system for the management and distribution of scientific and decision-making data to final users.

Key words: climate changes, modeling, satellite techniques, agro ecosystem

Introduction

The impact of climate changes on the environment and, implicitly, on the fruit tree agro ecosystem is a comprehensive and complex topic. The aim of POMOSAT project is to investigate the potential impact of climate changes on fruit tree species development and growth, and the impact of the diseases and pests affecting these cultures, using regional climate numeric models, impact models and satellite monitoring techniques.

Materials and methods

POMOSAT project is financed by the CEEX Romanian Research Program and is led by the Research Center for Integrated Fruit Growing, University of Agronomic Sciences and Veterinary Medicine Bucureşti. The other partners involved in the project are: National Meteorology Administration, Mathematics and Computer Science Department from Bucureşti Constructions Technical University (UTC) and Dambovita Fruit Growers Association.

The main objectives of the project are: a) to map the studied fruit tree agro-systems, using satellite techniques; b) to create a space database (GIS) for the studied zones; c) to characterize the test zone climate evolution, using agricultural climate factor types

specific to fruit trees; d) to analyze the fruit tree plantations vegetation status, using conventional methods and satellite techniques; e) to monitor the pathogenic agents and populations of useful organisms within the studied fruit tree zones; f) to predict the potential impact of climate changes upon fruit tree plantations, by numeric simulations; g) to establish a correlative model between climate evolution and sustainable fruit farm management; and h) to create an interactive system for the management and distribution of scientific and decision-making data to final users.

Results and discussion

After two years of common research few results were achieved. There were acquisited and installed 5 weather stations of T707 type, equipped with Vaisala WXT510 combosensors, supplemented with WET – artificial leaf and C – Probe sensors for soil humidity, produced by the Austrian ADCOM Telemetry Metrilog concern (Picture 1, Picture 2).

There were collected phenological and agrochemical data from the field, monitored the pest and diseases evolution for the studied zones and predators populations. So fruit growing recommendations based on a thorough knowledge of the natural, biological and technological phenomena governing the fruit tree ecosystem were developed.

The monitoring of climate changes ensures an efficient management of natural climate and soil resources and reduces the negative impact of fruit growing and related activities upon the environment and the climate.

The development of modern information techniques and means of communication aims to develop the business environment in the field of fruit production, as well as their utilization to the benefit of the citizens carrying out such activities, and of the entire society in general.

The satellite images were processed in order to obtain the land cover map and to delineate the orchard surfaces and the vegetation state estimation (Picture 3, Picture 4). These maps reflect the current situation of orchards and their evolution in time.

Some of agro climatic indexes for fruit species were elaborated and it was calculated the Typical Meteorological Year for every studied area (Picture 5).

The evolution of the agricultural climate factors studied in the period 1961-2004 were graphically plotted. These data are used to characterize the climate evolution of those zones and to highlight previous climate changes, for the purpose of future estimates and forecasts.

Satellite image processing is used to calculate the vegetation values to be used for the spatial and temporal analysis of fruit plantations' vegetation status. The current condition of plantations, the attack level, the production, etc. can be highlighted based on certain mathematical and algorithm models created within the project.

A space database that contains satellite images was created and, climate parameters and data were collected during the measurement campaigns. The database is used to validate and adjust the climate model used for studying the climate impact upon fruit tree ecosystems.

Estimation of fruit production losses due to diseases and meteorological phenomena, such as: drought, heavy rains, frost, using the climate model, and issuance

of scientifically supported recommendations regarding fruit growing, under the form of sustainable production technologies for each fruit tree species are available for all the growers located in the studied areas.

All the data obtained and the mathematical models created were used for designing a professional web site (Picture 6) as an interactive system for the management and transmission of information to the beneficiaries – fruit farmers. These growers have free access to the consortium web page, which offer general information on their fruit tree zones, current meteorological data in real time and medium-term values, forecast and warning programs regarding the attack of diseases and pests for the application of phytosanitary treatments, drought and climate accident risks (frost, hail, etc.).

Conclusion

By creating a complex database of climate records, satellite images, field and laboratory observations and measurements, a sustainable fruit farm management system can be developed.

Acknowledgements

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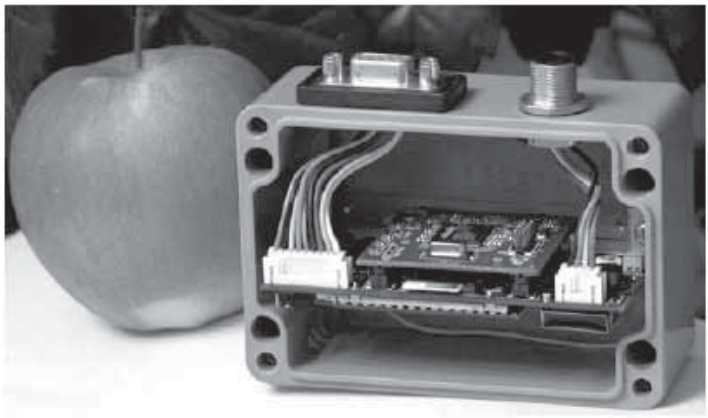
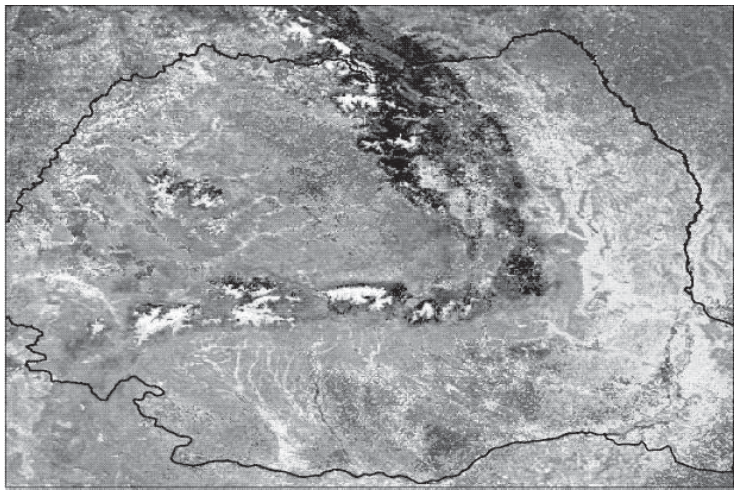
Picture 1. Metrilog weather station.

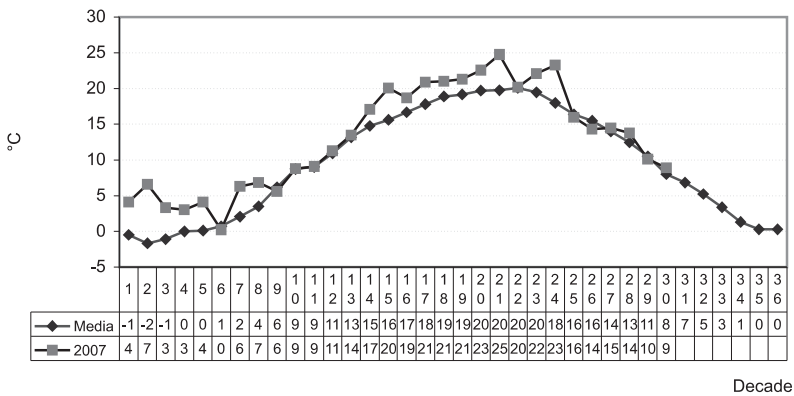


Picture 2. Module T707 the brain of ADCON Telemetry – Metrilog weather station.

Picture 3. Orchard planted areas determined with the program Corine Landcover.



Picture 4. Composed fault color 321 strips (NIR/Red/Blue) Spot-Vegetation Image (21.04.2007 – 30.04.2007).



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Media	-1	-2	-1	0	0	1	2	4	6	9	9	11	13	15	16	17	18	19	19	20	20	20	20	18	16	16	14	13	11	8	7	5	3	1	0	0
2007	4	7	3	3	4	0	6	7	6	9	9	11	14	17	20	19	21	21	21	23	25	20	22	23	16	14	15	14	10	9						

Picture 5. Decadal temperatures in Voinesti area in 2007, in comparison with the Typical Meteorological Year values.

Picture 6. Web page of POMOSAT project.

INFLUENCE OF SOIL MANAGEMENT TREATMENT ON ROOT SYSTEMS OF APPLE TREES

Valentīna SURIKOVA[1], Aldis KĀRKLIŅŠ[2], Edgars RUBAUSKIS[1], Māra SKRĪVELE[1], Vilnis BERLANDS[1]

[1] Latvia State Institute of Fruit-Growing
Graudu 1, Dobele, LV 3701, LATVIA
e-mail: valentina.surikova@lvai.lv
[2]Institute of Soil and Plant Science, Latvia University of Agriculture
Liela Street 2, Jelgava, LV - 3001, LATVIA
e-mail: aldis.karklins@llu.lv

Abstract

The aim of this research was to clarify root distribution of apple trees on the dwarf rootstock B 9 depending of soil management treatment. The investigation was done on the base of an existing trial planted in 1997 with cultivar `Melba`, at 1.5 x 4 m distances. In the strips the trial had the following soil management treatments: control, sawdust mulch and fertigation. For characterizing of root distribution, trenches were dug near the trees perpendicular to the row of trees, 1.2 m deep, 2.6 m long and 0.8 m wide. The roots were coloured to identify them and differentiated by size, and counted using a frame with 0.15 x 0.15 m pixels. It was found that the main mass of apple tree roots (80 % of them) on dwarf rootstock B 9 were distributed depending of soil management treatment – in treatments with mulch and fertigation till 0.30 depth, in control till 0.45 m depth. However, in horizontal direction of both sides from the tree trunk it was till 0.75 m for all treatments – no significant differences. The total amount of roots differed also depending of soil management treatment – there were significantly more roots in the treatment with mulch comparing with control.

Key words: amount of roots, fertigation, *Malus*, root distribution, sawdust mulch

Introduction

Since the 1990ties apple trees are mostly grown on vegetative clone semi-dwarf and dwarf rootstocks in Latvia. The distribution of such rootstock roots and influence of different factors on it have been investigated very little. In Latvia until now such research was done with seedling apple rootstocks (Dimza, Gross, 1994). However, the build-up of root systems of vegetative propagated and seedling rootstocks differ.

In other investigations it is pointed out that the largest part of tree roots is found near the soil surface, where the cultivated soil is not so dense, lighter, with optimal moisture level and nutrients. Some of authors indicated that under the mulch one can find more fine roots of apple trees (Mmolawa, Or, 2000; Faber et al., 2001; Alijev, Poachev, 2007).

It is known that using drip irrigation the largest concentration of roots is close to the emitter (dripper), especially in the 20 cm deep layer, moreover, in countries with dryer conditions root amount was significantly larger than without irrigation (Neilsen et al., 1997; Hee – Myong, 2001). Also researchers have marked out that 70 % of the mature apple tree water uptake occurred in the top 0.4 m of the root zone, in which approximately 70 % of the fine roots were located (Green, Clothier, 1999).

The aim of this study was to clarify the root distribution of apple trees on dwarf rootstock B 9 depending of soil management treatment in the conditions of soil and climate of Latvia.

Material and methods

The investigation was done on the base of an existing trial planted in 1997, with tree spacing 1.5 × 4 m, Latvia State Institute of Fruit-Growing, Dobele (Rubauskis et al., 2004). This investigation was done for the cultivar `Melba` on vegetative propagated dwarf rootstock B 9.

The trees were planted in soil which varies from haplic luvisol (super eutric) to luvisol (hypereutric), soil texture – loam (L) and sandy clay loam (SCL). In the plot the average potassium content was 146 – 268 $mg \cdot kg^{-1}$ (ppm), phosphorus was 181 – 585 $mg \cdot kg^{-1}$ (ppm), pH_{KCl} 5.7 – 6.7 and organic matter 21 – 36 $g \cdot kg^{-1}$ of soil.

In the strips the trial had the following soil management treatments (SMT): control, sawdust mulch and fertigation. The irrigation was done if there was not enough precipitation and soil moisture – measurements of soil moisture content and amount of precipitation were also done.

For characterizing of root distribution, in 2007 trenches were dug near the trees perpendicular to the row of trees, 1.2 m deep, 2.6 m long and 0.8 m wide. This was done for each SMT in three replications. Roots were identified, first spraying the profile with white colour, then scraping off the soil of profile – leaving coloured roots. The roots were counted using a frame with 0.15 x 0.15 m pixels and differentiated by size into the following groups: VF – very fine (diameter of root <1 mm); F – fine (1 – 2 mm); M – medium (2 – 5 mm); C – coarse (5 – 15 mm); VC – very coarse (>15 mm) roots.

The data were evaluated using variance analysis, Fisher test with program MS Excel.

Results and Discussion

The obtained data showed that the soil management treatment had significant influence on the distribution of apple roots (Figure 1). Significantly larger amount of roots was obtained in the treatment with mulch if compared with control. Mulch was put on field and renewed totally three times in period of 1997–2008. At the time of root investigation the sawdust mulch layer had decomposed. In the treatment with fertigation a tendency was observed of increased amount of roots comparing with control, but it was not significantly different, also there was no significant difference with the mulch treatment. In some cases it was not the same as found in other studies (Anderson et al., 2000; Hee – Myong, 2001), where it was observed that roots grow more intensively at the optimal soil moisture. Obviously, under influence of climate conditions there was enough moisture for the growth and development of roots under the mulch. Also possibly a better temperature regime for roots exists in soil under the mulch. With good temperature and moisture interaction in soil root development and growth had a good chance. Possibly higher temperature under the mulch layer increased the uptake of nutrients, improved the soil physical properties, thereby it could have positive influence on the root system (Forshee et al., 1999).

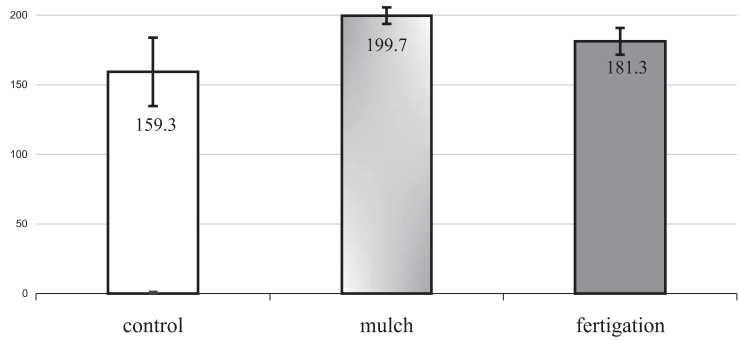


Figure 1. The total amount of roots in the soil profile

In an investigation of the influence of soil moisture on grape roots in Pennsylvania, USA (Anderson et al., 2000), it was found that the roots have a tendency to be more dense in places with higher soil moisture. In this research of the amount of roots and their size differences it was found that in dry soil grape-vines had less fine roots than in optimally moist soil. This possibly can be found for apple trees also, especialy on dwarf, vegetative propagated rootstocks, because the main mass of the fruit tree roots is located in the zone of moistened soil (Brawdo et al., 1992).

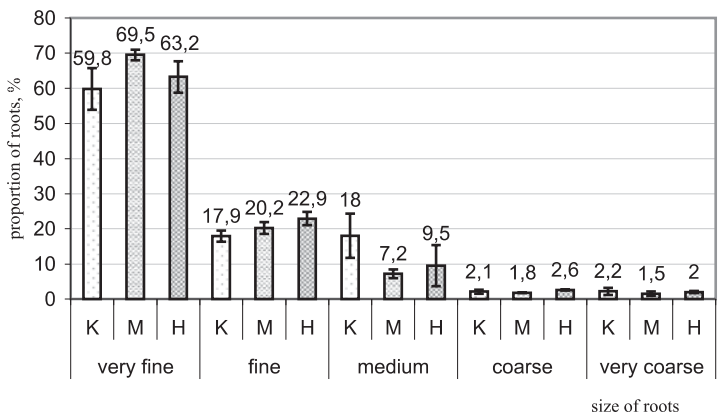


Figure 2. Root distribution in groups (K- control, M – mulch, H – fertigation)

In this trial, if the roots were separated by size, approximately half (~ 59 %) of them were very fine – their diameter was not larger than 1 mm in the control treatment. Significantly larger amount of very fine roots was in the treatment with mulch (69 %). The good growing conditions in this trial were proven by the 70 % of very fine roots in all apple root system. When performing similar analysis, our data showed that the growth conditions were not good enough not only in the control, but also in the treatment with drip irrigation (fertigation) in the trial at Dobele (Figure 2).

In the control and fertigation treatments the fine roots (diameter 1 – 2 mm) were one third of the total amount of roots, but in the treatment with mulch they were approximately one fifth of all roots (Figure 2). There were no significant differences between control and fertigation for this fraction of roots.

In the control there were significantly larger share of medium size roots (diameter 2 – 5 mm) comparing with the mulch and fertigation treatments (Figure 2). The coarse and very coarse fractions of roots were not significantly different between the treatments.

In the control approximately 35 % of total amount of roots were located no deeper than 15 cm, besides, it was almost twice less than the amount of roots in treatments with the mulch and fertigation in the same depth. In the control in average 75 % of the total amount of roots reached the 30 cm deep soil layer (Figure 3).

In the control 90 % of roots or the main mass of roots was located in soil till 45 cm depth. In treatments of mulch and fertigation the main mass of roots was located till a 30 cm deep soil layer.

In the treatment with mulch the roots concentrated near soil surface. Already at 0–15 cm depth there was found more than a half of the total amount of roots, the depth of 30 cm was reached by the main mass of roots. In the soil layer of 15 – 30 cm of soil profile the dispersion of roots was two times larger than closer to the soil surface. It shows that the dispersion of moisture was not equal in this soil layer comparing with shallower soil layer in this trial. In the treatment with mulch the roots of other soil layers were only a small part of the total amount, only some roots were found in the 60–70 cm depth.

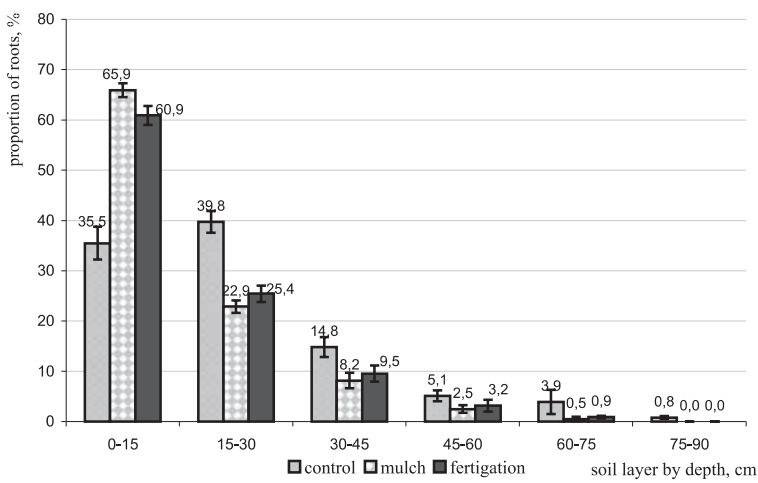


Figure 3. Root distribution depending on soil layers

Using drip irrigation a large part of roots were found already in 0–15 cm deep soil layer, the main mass of roots were found till 30 cm depth. Similarly as in the treatment with mulch, when using drip irrigation only some roots were found in 60–75 cm depth. The dispersion of roots in soil profile was comparably smaller in the treatments with fertigation which testifies the uniformity of soil moisture.

A similar investigation about moisture influence was done in Japan with ornamental plants *Artemisia pedunculosa, Polygonum cuspidatum* and *P. weyrichii*. Digging out the plants and grouping their roots into groups – fine, medium and coarse, the researchers found out that in soil with uniform moisture more than 90 % of roots were found in half

of the volume occupied by roots. For example, if roots were found till 40 cm deep, then 90 % of them would be in the soil layer till 20 cm depth (Anisuzzama et.al., 2002). In our study the roots were found to 90 cm depth. In the control variant about 75 % of all root mass was found till 45 cm depth but in the mulch and fertigation variants from 87 % to even 85 % of the total root mass was located till 45 cm depth.

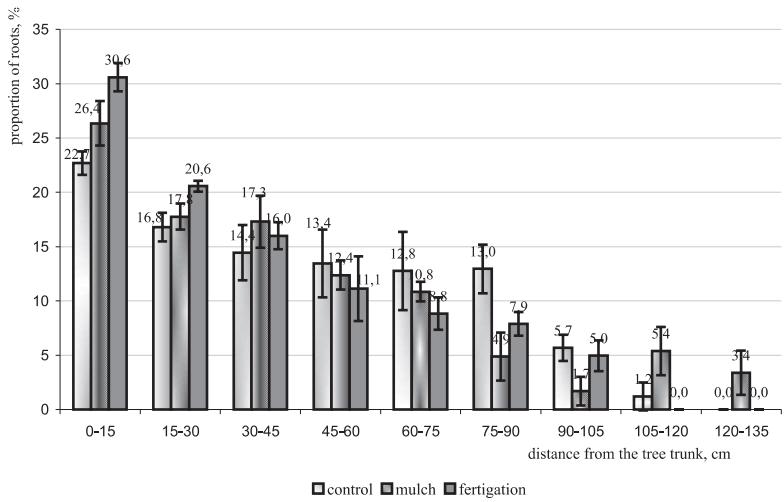


Figure 4. Root distribution depending of distance from trunk

Drip irrigation can cause the "effect of container" or a limited volume where proper conditions for root development and growth exist (Ben–Asher, Silberbush, 1992). Normally, in the zone of moistened soil the main mass of roots is located, but outside of it a negligible part of the root system (Brawdo et al., 1992). In our trial when analyzing the distribution of roots between treatments no significant difference was found. In all treatments the main mass of roots was located in horizontal direction till 75 cm from the trunk of tree (Figure 4). In the treatment with irrigation half of roots were found in the 0–30 cm distance from the apple trunk. Moreover, it was significantly more than in the control and treatment with mulch, where in the same distance 40 % of roots were located. The largest distance from trunk, where the roots were found, was 1.05 m in the treatment with fertigation, 1.20 m – control and 1.35 m – with mulch residue at the moment of investigation.

Conclusions

It was found that the main mass of apple tree roots (80 % of them) on dwarf rootstock B9 were distributed depending of soil management treatment – in treatments with mulch and fertigation till 0.30 depth, in control till 0.45 m depth, however, in horizontal direction on both sides from the tree trunk it was till 0.75 m for all treatments – no significant differences.

The total amount of roots also differed depending of soil management treatment – there were significantly more roots in the treatment with mulch comparing with control.

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THE POSSIBILITIES OF ORGANIC RASPBERRY PRODUCTION SETTING A HUNGARIAN EXAMPLE

Gábor VÉTEK, Béla PÉNZES

Corvinus University of Budapest, Faculty of Horticultural Science,
Department of Entomology, H-1118 Budapest, Villányi út 29–43, Hungary
e-mail: gabor.vetek@uni-corvinus.hu

Abstract

Red raspberry is one of the most important soft fruits grown in the temperate zones of Europe, mainly in the hilly-mountainous parts of the countries. Besides the appropriate climatic and soil conditions the possibilities of organic raspberry production is determined by various factors. The choice of high quality cultivars, which are not susceptible to harmful pests and diseases, the use of healthy planting material, the application of appropriate growing techniques and environmentally friendly plant protection methods are all inevitable. Improvement of marketing communication strategies is also necessary to make the special value of organic products acknowledged by the buyers and to make the consumers inclined to pay extra price for them. The aims of this paper are to overview the major conditions of organic raspberry production and to give an example from Hungary. The presented plantations are located near the village of Berkenye, where raspberry has been grown according to the rules of organic production for more than a decade and regular pest monitoring has been carried out by the authors since 2003. Under Hungarian conditions cv. 'Fertődi zamatos' proved to be an outstanding variety for the purpose of organic production. The autumn-fruiting cultivar, 'Autumn Bliss', can also be recommended to growers if grown in the annual system, but its susceptibility to grey mould and some other diseases requires more consideration before making a decision to establish a plantation. The investigation of market conditions has to be emphasised in order to make organic raspberry production as profitable as possible.

Key words: 'Fertődi zamatos', Hungary, organic raspberry production

Introduction

Red raspberry (*Rubus idaeus* L.) is grown in many parts of the world. It is a high value soft fruit crop, the production of which is concentrated in regions where climatic, soil and economic conditions are all suitable for growing. Supplying the market with raspberry grown according to the strict rules of organic production is a challenge for growers and researchers and a demand from consumers. Many different factors influence the success of biological raspberry production and these factors vary depending on countries, growing regions and even plantations. Among the most important requirements for successful raspberry production the use of pest- and pathogen-free planting material of high quality cultivars grown in appropriate systems and the application of environmentally safe pest management methods have to be emphasised besides the conditions mentioned above. The good marketing strategy is also indispensable without which organic raspberry production can be hardly profitable.

Some important conditions of organic raspberry production.

In Europe, wild raspberry can mainly be found in mountainous areas characterised by relatively cool, rainy weather and mildly acid soils. It is a frequent plant species in

the zone of beech forests, and its populations usually grow at the sunlit edge or clearings of woods near rivers or streams. As a need for successful production, the traditional raspberry growing areas have been established in those parts of the countries where the climatic and soil conditions mentioned above can be adequately provided. The highest crop can be expected if raspberry is grown on fertile, medium heavy, airy, permeable and approx. 6.5 pH soils with optimal water, nutrient and organic matter supply (Kollányi, 1990; Leposavić et al., 2004; Papp, 1999). In spite of the fact that the rate of hilly-mountainous regions of Hungary is relatively small, our raspberry production has a big tradition and the aromatic taste of the Hungarian raspberry is well-known among European consumers.

Besides the choice of appropriate field for large-scale raspberry production, the importance of the use of high quality cultivars has to be emphasised as well, if organic production is aimed by the grower. Nowadays, there is a range of different cultivated varieties of *Rubus* due to breeding work in many parts of the world including Hungary (Kollányi, 2005). The main objectives of raspberry breeding vary depending on the region because of differences in climatic conditions, dominance of pests and diseases and demands of growers and consumers. Nevertheless, all the breeding programmes and researchers dealing with raspberry have some aims in common. These are identifying and incorporating sources of resistance to the most dangerous pests and pathogens together with improving quality from other aspects such as finding cultivars capable to produce high yields of excellent quality or tolerant to winter frosts. This often means a big challange for breeders as it is not easy to find plants which satisfy all of the expectations (McNicol, 1997). That is why other techniques (e.g. special growing ways and environmentally safe control methods) are required besides searching for sources of plant resistance.

As far as cultural techniques are concerned, there are different possibilities. The grower has the chance to choose among them after making a decision taking into consideration the aim of production. For example, if the yield is planned to be sold as fresh fruit on the market out of the season, then an autumn-fruiting cultivar characterised by a special supporting system in the field is needed in case of some cultivars (e.g. 'Autumn Bliss'). Another example may be the growing of some traditional cultivars which are suitable for mechanical harvest. In this case, the distance between rows has to be increased. In organic production, it is recommended to growers to avoid mechanical harvesting because of many reasons. On the one hand, the wounds on canes caused by the machine can be infected by different fungal pathogens. Among these, the most common one isolated by Williamson and Hargreaves (1978) was *Leptosphaeria coniothyrium*, which is the causal organism of cane blight. On the other hand, the insect contamination of harvested fruit may be considerable, too. The removal of arthropods is difficult and expensive, but can not be omitted. Otherwise, the yield may be rejected either by the processor or the consumer because of their high quality requirements (Gordon et al., 1997; Shanks, 1991). In conventional raspberry plantations the elimination of arthropods before mechanical harvest can be solved by applying broad-spectrum, short-residual insecticides (Shanks, 1991). However, this can not be carried out and is not desirable either in organic production because of the beneficial insects

often present in large numbers in the field playing an important role in the control of pests.

Plant protection is one of the crucial points of organic raspberry growing. Each soft fruit species has a special insect fauna and a range of characteristic diseases. This is true of red raspberry as well. Consequently, the plant protection methods which have already proved to be suitable for application against pests in other fruits are needed to be improved. In some European countries, significant effort has been made to develop IPM technologies in raspberry, but this can not be said to be common in Europe (Gajek and Jörg, 2003; Cross and Berrie, 2006). In order to give an efficient protection against pest and pathogen species extended research is required to reveal their biology under different circumstances. It has to be emphasised that due to the variable climatic conditions, growing techniques and pesticide usage in Europe, there are some differencies in the species composition and also the life cycle of dominant insects and fungal pathogens. For instance, while in the UK the large raspberry aphid (*Amphorophora idaei*), raspberry cane midge (*Resseliella theobaldi*) and raspberry beetle (*Byturus tomentosus*) are mentioned as the major pests of raspberry (McNicol, 1997), in Serbia, besides the aphids (*Aphis idaei* and *Amphorophora idaei*), the strawberry blossom weevil (*Anthonomus rubi*), raspberry mite (*Phyllocoptes gracilis*), and, in dry years, the two-spotted spider mite (*Tetranychus urticae*) are indicated as dominant arthropod pests (Milenković and Stanisavljević, 2003). In those countries where aphids occur in large numbers in commercial plantations regularly, the importance of aphid-transmitted viruses can be higher. According to a pest monitoring in Hungary, which has been carrying out for more than 30 years in raspberry plantations, a significant change has been observed in the dominance of pests. The rose stem girdler (*Agrilus cuprescens*) has become the major enemy of raspberry plants while the imoprtance of raspberry cane midge has decreased significantly, partly due to the resistance breeding programmes in Hungary (Szántóné Veszelka and Fajcsi, 2003). On the basis of these facts, it can be summarised that scientific research and monitoring of pests is essential, however, the grower's experience is also indispensable so that we can assess the significance of pests and diseases in the most important raspberry growing areas of a country. Having sufficient knowledge on the species composition of a raspberry plantation, including the beneficial arthropods as well, decision-making on the necessary plant protection methods will be easier and, what is more, more accurate and rational protection technologies will be possible to plan and apply.

In organic production the number of pesticides allowed for application is quite limited. For example, the use of systemic insecticides and fungicides is not permitted, and there are only a few contact ones which can be used in plant protection. Weed control also has to be carried out by environmentally safe methods, which usually means regular mechanical soil cultivation or mowing the grass-covered space between rows. The way of nutrient supply of plantations and the type of fertiliser is stricly controlled, too. These restrictions have to be kept and the growers of organic raspberry are supervised by different national organisations. On the other hand, the appearance of an organic product on the market is welcomed, and the firm limitation of chemicals in raspberry production agrees well with the increasing demands of consumers. Unfortunately, it is by

no means certain in each case that consumers are willing to pay extra price for the fruit containing no pesticide residue, and the experise needed for organic raspberry growing is not always acknowledged by the consumer either. Hence, organic production may not be profitable in every case. That is why marketing strategies need to be developed, and a better protection of growers' interests is required when selling raspberry coming from biological production.

Materials and methods

The advantages and disadvantages of different raspberry cultivars and cultivation methods applied at the region of Berkenye, Nógrád county, a traditional growing area of Hungary, have been investigated by the authors since 2003. Assessment of damage caused by different harmful organisms has been carried out by regular examinations and collections of plants in 7–14-day intervals in each vegetation period. A part of the results has already been presented in previous papers and the most important points are summarised here. The effectiveness of environmentally friendly plant protection methods including cultivar usage, growing techniques and pesticide application officially permitted in organic production in Hungary are discussed. Some suggestions for growers of other countries are also given taking into consideration the possible differencies in ecological and economical conditions.

Results and discussion

Climatic and soil conditions

The idea of organic raspberry production was put into practice in the northern, hilly-mountainous region of Hungary, near the village of Berkenye more than a decade ago. The raspberry plantations here are about 200–250 m above sea level in southwestern and northeastern exposures. The annual mean rainfall is about 500 mm in this region, which is under the optimal level for raspberry production. Hence, a dripping irrigation system supplies the plantations with the necessary water, which is provided by a reservoir built at the nearby stream. The annual mean temperature is about 9°C, winter and early spring frosts similarly to dry and hot summer periods are not rare. Brown forest soils characterised by relatively low pH value, good mechanical structure and organic matter content can be found in this area.

Cultivars and growing methods

The dominant cultivar in the plantations is 'Fertődi zamatos'. It was bred at the Research Institute for Fruit Growing, Fertőd, Hungary (Kollányi, 1987). The mean features of the cultivar are as follows. It can be characterised by a vital, vigorous growth with a moderate primocane development and a hardly peeling bark (Kollányi, 1990, 2005; Vétek et al., 2006a). Due to this latter character, it is quite well protected against a very important cane pest, the raspberry cane midge (*Resseliella theobaldi*), and, consequently, it is usually hardly affected by fungal diseases associated with the insect. According to our observations, the cultivar shows a good resistance also to diseases which infect both canes and fruits. Kollányi and Kollányi (2005) found no symptoms of infection caused

by *Elsinoë veneta* on this cultivar. A remarkable resistance to grey mould caused by *Botrytis cinerea*, the most serious disease of raspberry fruits worldwide, and to powdery mildew (*Sphaerotheca macularis*) was also established (Kollányi, 1999, 2002). The canes of 'Fertődi zamatos' were observed to be quite tolerant to winter frosts as well, contrary to 'Tulameen', which, nevertheless, is also hardly damaged by the raspberry cane midge under Hungarian conditions. As far as the fruit of 'Fertődi zamatos' is concerned, further features are its medium or large size, red colour and excellent flavour. Due to the facts that the berries remain their firm flesh and attractive colour in the process of ripening, 'Fertődi zamatos' is highly suitable both for fresh consumption and freezing. The cultivar is a middle-late ripening one, and it can produce high yields (Kollányi, 1990, 2005).

'Fertődi zamatos' is grown on a comlex post and wire system with 2.2–2.5 m between rows, and the space between rows is covered with grass or in some cases with clover for some nutrient supply and mown if necessary, or they are mechanically cultivated to control weeds. The rows are hoed for the same purpose. Between neighbouring posts, two wire rows are applied because of the vigorous growth. Approximately 8–10 canes are left per metre and 2–3 canes are tied together to the upper wire. The pruning comprises the following methods:(1) Removal of first flush when the primocanes are about 15–20 cm high. This can be carried out as the cultivar is able to produce adequately strong, new primocanes some weeks later and as the regular irrigation provides a well-balanced development of the plants. (2) Cutting out of fructocanes after harvest and selection of well-developed, healthy canes that will bear fruits the following year. (3) Cutting back of the top of canes at a height of approx. 1.8 m. The prunings serve to provide high yields each year and to prevent infections caused either by diseases or pests.

The other main cultivar in the plantations is 'Autumn Bliss'. This autumn-fruiting variety was bred at the East Malling Research, UK (Kollányi, 1990). It can be characterised by a special, bushy growth and a readily peeling bark due to which it is susceptible to cane midge damage (Vétek et al., 2006a) and is often infected by *Didymella applanata*. According to our observations its canes as well as its relatively soft fruits are frequently damaged by grey mould (*Botrytis cinerea*), so this fungal pathogen can be said to be the most important one affecting the cultivar. However, it shows a good resistance to *Elsinoë veneta* (Kollányi and Kollányi, 2005) and contains some resistance genes against aphids, too (Schaefers and Gordon, 1991). The small raspberry aphid (*Aphis idaei*), which was identified in the growing area, was found only in small numbers in the 'Autumn Bliss' plantation (Szabó et al., 2008). The features of the fruit are its large size, dark red colour and pleasant taste. It can produce high yields (Kollányi, 1990) and is primarily suitable for fresh consumption out of the season, from the second half of July until the first frosts in autumn under Hungarian conditions.

A characteristic growing method is used in the investigated 'Autumn Bliss' plantation. The distance between rows is 2.2–2.5 m. It is not recommended to decrease this distance as primocanes show a bushy form in the second half of the vegetation period tightening the area between the rows of plants. The posts are smaller (about 1 m high) contrary to those used in traditional plantations, and a pair of strings is stretched between neighbouring stakes at a height of approx. 0.8 m to adjust the plants

by arranging the growing canes between the strings. No other supporting system is applied in this 'Autumn Bliss' plantation, but net-like ones, originally used in carnation growing, are also known to be used in the production of this cultivar. Mechanical weed control is necessary especially in the first part of the vegetation period as 'Autumn Bliss' is difficult to be hoed later because of its bushy growth. The pruning comprises only one action: Removal of all canes at soil level after the date when harvest becomes no longer economic usually due to the lower temperature hindering fruit ripening and the frequent rains increasing the risk of damage caused by grey mould on berries.

In all the raspberry plantations, biofertilisers containing organic material and microelements are applied twice to provide nutrients for sufficient plant growth. However, regarding the efficacy, it seems to fall behind that of when certain chemical fertilisers are applied, which are officially not permitted to be used in organic growing. Nevertheless, the elaboration of a more detailed biofertilisation program could give a chance to improve yield quality and quantity. Some good results are known from growers who apply biofertilisers regularly in blackberry plantations in the same region.

Plant protection

As it was mentioned above, the number of pesticides allowed for application in organic raspberry production is limited. At present, among insecticides, only *Bacillus thuringiensis* var. *kurstaki* is officially allowed for application against larvae of moths in raspberry in Hungary. However, this group of pests is often attacked by numerous parasitoids and thus is usually of low importance under our conditions (Balázs et al., 1998). As far as further pests and diseases are concerned, the following results of our observations in the 'Fertődi zamatos' plantations can be shown. The characteristic pseudo-galls on canes caused by feeding of the endophagous larva of rose stem girdler (*Agrilus cuprescens*) can often be found. The larva of the pest overwinters inside living canes above these gall-like swellings, and after pupation next spring, the emergence can be observed from late spring to the beginning of summer. After mating of adults, eggs are laid on the surface of stems. The damage caused by adult feeding on leaves is negligable contrary to that of the larva, which developmental stage gets into the cane immediately after hatching. At present, the only reliable control technique against this pest is the elimination of damaged first-year canes after harvest, during the selection of canes in case of traditional cultivars. The cultivation system of 'Autumn Bliss' makes it impossible for the larvae of the pest to survive within the plantation as all canes are cut and annihilated after the end of harvest. In this latter case, the oligophagous jewel beetle is able to reinfest 'Autumn Bliss' only from neighbouring blackberry and traditionally grown raspberry plantations where damaged canes with overwintering larvae may occur in spite of careful prunings, or from rose bushes growing wild, which should be eliminated to prevent *Agrilus cuprescens* attacks. A hymenopterous parasitoid, *Tetrastichus heeringi*, plays an important role in the control of the pest.

The other major cane pest in both plantations is the raspberry cane midge (*Resseliella theobaldi*). However, it can not give rise to significant cane death because 'Fertődi zamatos' shows a relatively good complex resistance to this pest and associated fungal pathogens as mentioned above. Nevertheless, cutting out the first flush of primocanes,

which may split early in the year and enables first generation midge adults to lay eggs in these cracks, hinders the pest to reach extremely large populations. The method has to be carried out in an environmentally safe, e.g. mechanical way. In those areas where the pest and the associated fungal pathogens mean a real problem in raspberry production, the use of a BCA, *Bacillus thuringiensis* subsp. *israelensis* can be recommended to control midge bight (Shternshis et al., 2002) besides the good cultivar choice and growing technique. However, the efficacy of this biopesticide in the mentioned respect can not be confirmed by other experiments (Antonin et al., 1998, Baroffio, pers. comm., Vétek et al., unpubl.). Cane death does not mean any problem in the annual growing method of 'Autumn Bliss' in spite of the fact that this cultivar is largely exposed to midge attack. Cane midge populations can be controlled to some extent by a chalcidoid species, *Aprostocetus epicharmus*, too (Vétek et al., 2006b), though the presently used growing technique of this cultivar is not suitable to save the beneficial insect mentioned, because its larvae overwinter on canes which are eliminated from the plantation according to this technology.

Although the two cultivars are quite well protected against cane pests and diseases due to cultivar characteristics in case of 'Fertődi zamatos' and the growing method in case of 'Autumn Bliss', fungicides containing copper and sulphur, both allowed in organic production, are sprayed three times in the traditional and once or twice in the autumn-fruiting plantations from April to May to reduce the risk of possible fungal infestations. Sulphur can give protection against mites, the significance of which seems to be increasing in the region as summers are getting warmer and drier.

As far as aphids and aphid-borne viruses are concerned, neither of the two varieties is significantly affected. As the nitrogen supply is limited, no outbreaks of aphid populations are expected under average climatic conditions of this area. The summer is often warm here, which is not favoured by raspberry aphids, and natural enemies also contribute to keeping aphid populations at a low level. A typical problem caused by aphids may be the insect contamination of harvested fruit, but this is avoided by hand-picking instead of mechanical harvesting. Symptoms of aphid-transmitted viruses have not been detected yet. On the other hand, RBDV-like symptoms on 'Autumn Bliss' can be discovered especially on its leaves at the beginning of the vegetation period. Laboratory tests have not been carried out yet, but the causal organism is likely to be the pollen-borne raspberry bushy dwarf virus (RBDV). It is able to infect this cultivar (Mavrič et al., 2004), and typical symptoms such as chlorotic leaves and crumbly fruits have been observed. Closer investigation is needed to identify the pathogen. The most important thing in order to avoid RBDV infestation when establishing a new 'Autumn Bliss' plantation is to use healhy, virus-free planting material far enough from possibly infested plantations.

Among the pests and diseases of the flower and fruit, grey mould (*Botrytis cinerea*) means a problem, but higher damage can be observed only in the 'Autumn Bliss' plantations. The protection against this pathogen has still not been solved satisfactorily. Although *Trichoderma harzianum* for the control of the fungus is officially permitted in organic raspberry production in Hungary, on the basis of growers' reports, no remarkable results have been obtained in practice. Quick, well-organised picking seems to be the

only solution to avoid considerable yield loss of 'Autumn Bliss'. As its canes are also highly susceptible to this disease, the applied growing method together with the removal of all plant debris may also help to reduce the risk of infection. Fortunately, the raspberry beetle (*Byturus tomentosus*), which is the most important pest of the generative parts of raspberry in many raspberry growing areas of Europe and is an important indirect causal agent of grey mould infestations which is associated with its feeding damage, does not mean a problem in Hungary, no significant damage has been reported for many years. The reason for this is not clearly understood, but the general application of pyrethroids in many raspberry growing regions in Hungary might have contributed to the reduction of *Byturus tomentosus* density (Szántóné Veszelka and Fajcsi, 2003). If raspberry beetle damage became regular, a possibility of environmentally safe control measures could be the application of volatile-enhanced white sticky traps used with the "lure and kill" technique, which could decrease adult populations to such an extent that larval damage may remain under economic treshold (Woodford et al., 2003). The details of this control method need to be worked out by further experiments (Trandem et al., 2007). On the other hand, as the main time of emergence of the raspberry beetle does not coincide with the flower development and fruit ripening of the indicated autumn-fruiting cultivar, the growing technique of 'Autumn Bliss' can also be said to be a good, alternative plant protection method against this pest.

Conclusions

The possibilities of organic raspberry production is determined by many factors. Optimal climatic and soil conditions together with the choice of high quality cultivars, use of pest- and pathogen-free planting material, application of appropriate growing techniques and environmentally friendly plant protection methods are all inevitable to reach high yields. In order to extend the group of farmers who would be inclined to take part in organic raspberry production, growers' attitude needs to be changed from some aspects. For example, the rate of plantations where conventional plant protection methods are common in practice by the application of broad-spectrum pesticides against organisms the importance of which is often overestimated or simply not established is still quite high. Among precarious market relations it is not easy to persuade growers to give up their routine cultivation practices by changing cultivars or growing methods. However, the use of modern varieties with appropriate growing techniques may contribute to the reduction or even the avoidance of sprayings with chemicals, and the pesticide-free product is welcomed by both the processor and the consumer. Improvement of marketing communication strategies is also necessary to make the special value of organic products recognised and acknowledged by the buyers and to make the consumers inclined to pay extra price for them. Under Hungarian conditions, there is the advantage of having growing traditions with considerable experience. The possibility of choosing amongst a range of Hungaian-bred raspberry cultivars such as 'Fertődi zamatos' or other varieties from the Research Institute for Fruit Growing of Fertőd is a great advantage, too, as these raspberries are well-adapted to our continental climatic conditions. A great interest is shown to our high quality raspberry cultivars by various companies from different countries of Europe and even Asia. Breeding and plant

protection research have reached a remarkable level, but further work is required. The good geographical position, suitable growing regions, producers' experience, presence of raspberry research centres and the relatively few problems with pests and diseases can be the major chances of Hungary in the increasing competition to produce healthy fruit of excellent quality originating from organic production.

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Part D

"ENVIRONMENT-FRIENDLY PLANT PROTECTION IN ORCHARDS"

THE DAMAGE OF THE STRAWBERRY BLOSSOM WEEVIL (*ANTHONOMUS RUBI*) DEPENDING ON RASPBERRY CULTIVARS AND MULCHING IN ESTONIA

Liina ARUS[1], Anne LUIK[2], Asta LIBEK[1] and Kadri OLEP[2]

[1] Polli Horticultural Research Centre of the Institute of Agricultural and Environmental Sciences of the Estonian University of Life Sciences, 69104 Karksi-Nuia, Estonia, e-mail: liina.arus@emu.ee
[2] Department of Plant Protection of the Institute of Agricultural and Environmental Sciences of the Estonian University of Life Sciences, Kreutzwaldi St. 1, 51014 Tartu, Estonia

Abstract

The damage of strawberry blossom weevil (*Anthonomus rubi*) was estimated in the raspberry cultivars in collection of the Polli Horticultural Research Centre during the flowering periods of 2003-2007. The total number of flower buds was counted and inspected for damages in the plants of 14 cultivars ('Aita', 'Algonquin', 'Alvi', 'Arta', 'Glen Ample', 'Haida', 'Helkal', 'Ivars', 'Nagrada', 'Norna', 'Novokitaivska', 'Ottawa', 'Tomo', 'Veten'). In 2004, 2005 and 2007 there were no blossom weevil damages. In 2003 and 2006 damages were found. In both years the flowers of 'Glen Ample' were the least damaged ones (on an average 1.0%). Also 'Ivars' and 'Algonquin' flower buds had very little damage (2.0 and 2.5%, respectively). At the same time, 'Helkal' (23.8% of buds damaged) and 'Ottawa' (15.6%) were the most affected cultivars. The studies on different raspberry growing methods at the Polli Horticultural Research Centre in 2003 and at the Rõhu Experimental Garden in 2004 showed that strawberry blossom weevil's damages are also depending on mulching materials.

Key words: cultivars, mulches, raspberry, strawberry blossom weevil

Introduction

Red raspberry (*Rubus idaeus*) is the most important cane fruit grown commercially in Europe. Raspberry fruits are attacked by a wide range of insects and other pests that can reduce the quality and yield. The strawberry blossom weevil (*Anthonomus rubi* (Herbst)) is best known as a locally important pest of strawberry in several European countries, but it is also regarded as an important pest of raspberry in some warmer regions (Gordon et al., 1997). S. C. Gordon (2008) describes the strawberry blossom weevil as a 'minor pest' of *Rubus* that may become more important in Europe.

The management of raspberry pests relies on chemical pesticides; chemical preparations have dominated in the pest control. This has brought about the pollution of the environment and also kills the natural enemies of the pests. It is appropriate to study raspberry cultivars and their pest resistance, also the influence of growing technologies on the weevils damages to find alternative strategies in order to decrease insecticide use in this crop because consumers demand the fruits free from pesticide residues.

In Northern Europe, raspberry is often grown in 10–15-year rotation. To control weeds, raspberry rows are mulched with synthetic or organic mulches, but raspberry rows without any mulching materials are also very common. Mulching improves the

moisture conditions of soil by reducing water evaporation (Treder *et al*., 1993). Mulch is favourable for the development of the soil microorganisms and also affects soil temperature. Information about the effects of mulches on the pests of raspberry is very scarce.

The aim of this study was to investigate the influence of raspberry cultivars and different mulches (black plastic, sawdust, peat and straw) in plantations on the strawberry blossom weevil damage.

Materials and Methods

14 cultivars were inspected for the damage of the strawberry blossom weevil in the raspberry cultivar collection of the Polli Horticultural Research Centre during five years, 2003-2007. The cultivars were; 'Aita', 'Algonquin', 'Alvi', 'Arta', 'Glen Ample', 'Haida', 'Helkal', 'Ivars', 'Nagrada', 'Norna', 'Novokitaivska', 'Ottawa', 'Tomo', 'Veten'. In 2004, 2005 and 2007 there were no injuries therefore only data from the years 2003 and 2006 are shown in results.

An experiment of mulches was carried out in 2003 in the Polli Horticultural Research Centre and in 2004 in the Rõhu Experimental Garden. In Polli 2 cultivars ('Novokitaivska', 'Tomo') with 5 variants were used: sawdust, milled peat, straw litter, black plastic and soil surface without mulch. In Rõhu 5 cultivars ('Algonquin', 'Haida', 'Novokitaivska', 'Tomo', 'Veten') with 3 variants were used: black plastic + insectitcide Fastac, black plastic without any insecticide treatment and the soil surface without mulch.

In both testing places the plants were planted in rows with a spacing 3.0 m between rows and 0.5 m between plants, 10 plants per plot. Between raspberry rows thick grass, consisting mostly of Gramineae and clover, and including some weeds like quackgrass (*Elymus repens* L.) and dandelion (*Taraxacum officinale*), were growing. Black plastic was set before planting, organic mulches were added after planting: new layer of sawdust; peat and straw were added every spring. Cultural practises did not include any herbicides.

The whole number of flower buds per raspberry cane was counted and inspected for damages by strawberry blossom weevil. In all variants 4 x 3 flowering canes were inspected and percentage of damaged buds was calculated. The data were analysed with the one- and two-way ANOVA. Different letters in columns indicate significant differences between treatments ($P<0.05$, ns=not significant).

Results

Strawberry blossom weevil damage depending on cultivars. In both years (2003, 2006), when the damage occurred, flowers of 'Glen Ample' were the least damaged ones (on average 1.0% of all the flowers). Also 'Ivars' and 'Algonquin' had very few damages (2.0 and 2.5%, respectively). At the same time, 'Helkal' was the most injured cultivar (23.8%). 'Ottawa' was the second most injured cultivar (15.6%). In 2003 also 'Aita' and 'Alvi' had quite big number of damaged blossoms (18.8 and 15.8 %). On average of these two years data, cultivars 'Glen Ample', 'Ivars', 'Algonquin' and 'Haida' are quite resistant to the blossom weevil; cultivars 'Veten', 'Arta', 'Tomo', 'Alvi', 'Norna', 'Aita', 'Nagrada' and

'Novokitaivska' have medium resistance to the pest. Cultivars 'Ottawa' and 'Helkal' are quite susceptible to the strawberry blossom weevil (Table 1). In the experiment with different mulching materials in 2003 'Tomo' and 'Novokitaivska' had blossom weevil damages at the same level in Polli. The experiment in Rõhu showed that less injured cultivars were 'Haida', 'Algonquin' and 'Veten' (less than 10%); 'Tomo' was most injured (17%) (Figures 1, 2).

Strawberry blossom weevil damage depending on growing technologies. The experiment with mulches in Polli in 2003 showed that less damaged variants were black plastic and straw litter (22.4 and 23.4%, respectively) and the more damaged variant was sawdust (28.3%) (Figure 1). The Experiment in Rõhu showed that there were some

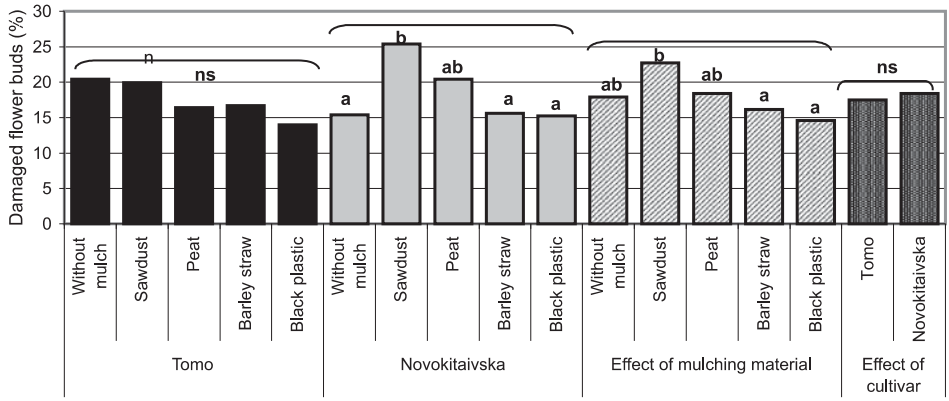

Figure 1. Flower buds damaged by strawberry blossom weevil (%) in 2003 in Polli depending on cultivars and mulching material. Different letters in columns indicate significant differences between treatments (Two-way ANOVA, P<0.05, ns=not significant)

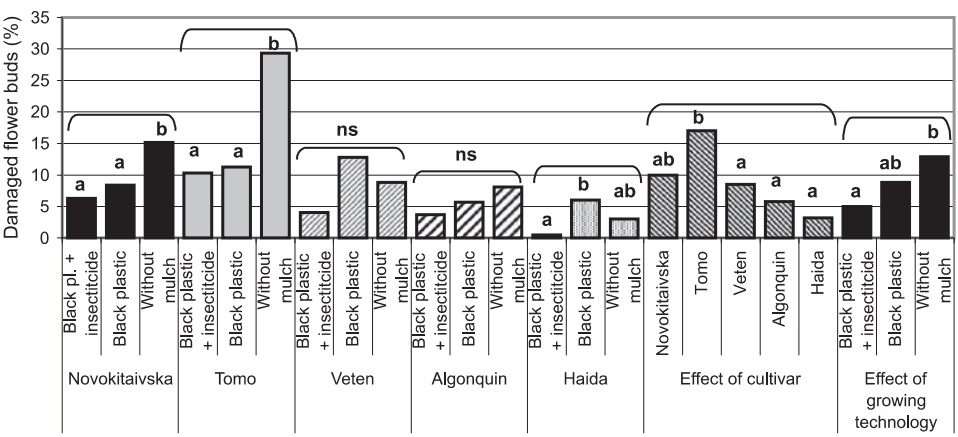

Figure 2. Flower buds damaged by strawberry blossom weevil (%) in 2004 in Rõhu depending on cultivars and growing technology. Different letters in columns indicate significant differences between treatments (Two-way ANOVA, P<0.05, ns=not significant)

differences between the variants with black plastic and without mulching. The flowers of plants from cultivars 'Tomo' and 'Novokitaivska' were significantly more damaged in the variant without mulch and less damaged in the variant with black plastic mulch. At the same time insecticide treatment did not have any positive influence on the decrease of strawberry blossom weevil damage. The number of damaged flowers in the cultivars 'Veten' and 'Algonquin' did not have differences in any variants. Only in the cultivar 'Haida' the insecticide treatment had a positive effect on the decrease of pest damage (Figure 2).

Discussion

The major damage of the strawberry blossom weevil is caused by the female weevil puncturing the flower stalk of the flower bud when she oviposits. The damaged flower bud ceases to develop and does not set fruit. One female strawberry blossom weevil can lay up more than 100 eggs (Tuovinen, 1997). In strawberry this pest can reduce the yield more than 60 per cent (Svensson, 2002). The damage of the blossom weevil depends on the cultivar, the year and especially on weather conditions during the spring.

Similarly to the weevil damage in the cultivated strawberry in Estonia (Kikas et al. 2007; Kikas and Libek, 2005) the blossom weevil damage in raspberry was high in the years 2003 and 2006; in 2004, 2005 and 2007 there was no injury or it was very low (less than 0.5 %) in all raspberry cultivars. The years during the trial were very different in respect to weather conditions, impacting the negative effect of unfavourable climate on the raspberry yield and the fruit weight. The negative effect on the formation of the yield was not noticed.

It has been stated that early blooming strawberry cultivars were more damaged than later blooming ones (Kikas and Libek, 2002). In the raspberry such preference by blossom weevil to the early blooming cultivars did not occur. 'Ivars', which is an early blooming cultivar had very little damage, at the same time cultivar 'Helkal', which is a late blooming cultivar had more damaged buds than the other cultivars.

The blossom weevil is known to be a cultivar specific pest in the strawberry (Simpson et al., 1997; Kikas and Libek, 2002). The same results have been noticed in this observation on the raspberry, where the cultivars 'Glen Ample', 'Ivars' and 'Algonquin' were less damaged and 'Ottawa' and 'Helkal' were most damaged in both years.

The evaluation in Latvia (Laugale et al., 2006) with three different organic mulches in strawberry showed that the living grass mulch facilitated the spread of blossom weevil. At the same time the percentage of damaged flowers was less numerous in variants with mulches of straw, savings and bare ground. Part of the strawberry blossom weevil's adults were over-wintering in the plantations where thick grass was growing between raspberry rows, like living mulch it creates good conditions for over-wintering. In our trial the raspberries growing with black plastic mulch were less damaged by the blossom weevil. Probably the variant without mulching and also some other organic mulches with grass growing between raspberry rows creates favourable conditions for the over-wintering of adults of the strawberry blossom weevil.

Conclusions

Strawberry blossom weevil damage on the raspberry flower buds is mostly depending on cultivars. Based on the trials, we can state that the invasion of the strawberry blossom weevil to the raspberry varied from year to year. Most of the years it does not cause any injuries and a special chemical control is not needed.

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Table 1. Percentage of flower buds damaged by the strawberry blossom weevil in 2003 and 2006. Different letters in columns indicate significant differences between treatments (One-way ANOVA, $P < 0.05$, ns = not significant)

	Cultivar	2003		2006		average	
1.	Glen Ample (SCRI)	1.9	a	0	a	1.0	a
2.	Ivars (Latvia)	4.0	ab	0	a	2.0	ab
3.	Algonquin (Canada)	4.1	ab	0.9	ab	2.5	abc
4.	Haida (Canada)	5.5	abc	1.7	ab	3.6	bc
5.	Veten (Norway)	7.9	bcd	2.4	b	5.2	bcde
6.	Arta (Latvia)	13.2	cdefg	1.8	ab	7.5	cdef
7.	Tomo (Estonia)	11.2	bcde	4.1	bc	7.6	def
8.	Alvi (Estonia)	15.8	defg	1.0	ab	8.4	cdef
9.	Norna (Norway)	8.9	bcd	8.7	cd	8.8	efg
10.	Aita (Estonia)	18.8	efg	1.0	ab	9.9	def
11.	Nagrada (Russia)	5.5	abc	16.6	de	11.1	fg
12.	Novokitaivska (Ukraine)	6.5	abc	16.1	de	11.3	fg
13.	Ottawa (Canada)	20.3	fg	10.9	d	15.6	gh
14.	Helkal (Estonia)	22.1	g	25.4	e	23.8	h

THE PREDATORY MITE *NEOSEIULUS CUCUMERIS* FOR CONTROL OF THE STRAWBERRY MITE *PHYTONEMUS PALLIDUS* ON STRAWBERRY RUNNER PLANTS

Valentina PETROVA[1], Ineta SAMSONE[2], Līga JANKEVICA[1], Zigrīda ČUDARE[1]

[1] Institute of Biology, University of Latvia, Miera str. 3, Salaspils LV-2169, Latvia
e-mail: valentina-2003@inbox.lv
[2] University of Latvia, Department of Plant Physiology,
Kronvalda blvd. 4, Riga LV 1010, Latvia

Abstract

The study was conducted in 2001 at the Institute of Biology, University of Latvia, and consisted of two experiments done under laboratory and outdoor conditions. The objective was to determine the possibilities of the predatory mite *Neoseiulus* (*Amblyseius*) *cucumeris* Oud. (Phytoseiidae) to control populations of the strawberry mite *Phytonemus* (*Tarsonemus*) *pallidus* Banks (Tarsonemidae) on strawberry runner plants before planting. The first experiment was carried out under laboratory conditions (average temperature – 21°C) from 17th to 28th of August. The RH was between 70 and 80%.

Runner plants of strawberry cultivar 'Honeoye' were naturally infested with *P. pallidus.* A single release of *N. cucumeris* was done with the predator: prey ratio 1: 5. The efficiency of *N. cucumeris* achieved 99.8 ± 0.9% on the 7th day and 100% on the 11th day after *N. cucumeris* release. The second experiment was carried out under outdoor conditions from 24th of August to 11th of October (average temperatures were 14.2°C in the end of August, 12.4°C in September and 10.6°C in the beginning of October). A single release of *N. cucumeris* was done with the predator: prey ratio 1: 10. After the 1st, 2nd, 3rd, 4th and 5th week from predator's single release the efficiency of *N. cucumeris* achieved 76.3 ± 10.4%, 88.9 ± 7.6%, 99.8 ± 0.8%, 99.9 ± 0.1% and 100%, respectively.

Better results were obtained in laboratory conditions with higher temperature and the predator: prey ratio 1: 5.

Key words: biological control, *Fragaria x ananassa*, *Neoseiulus cucumeris, Phytonemus pallidus*

Introduction

Many pests have affected the productivity of strawberry crop in Latvia. Some microorganisms, plants, and natural enemies have been utilised as biopesticides. Most of these agents are desirable alternatives to more toxic chemical pesticides and are also non-pathogenic for humans and domestic animals.

Introduction of phytoseiid predatory mites into strawberry fields is an effective method of control the two-spotted spider mite (*Tetranychus urticae* Koch) and the strawberry mite *P. pallidus* Banks in the UK, USA and Europe (Coop and Croft, 1995; Croft et al., 1999; Easterbrook, 2001; Petrova et al., 2002; Tuovinen, 2002). In Latvia, the two-spotted spider mite and the strawberry mite are widespread strawberry pests, which are capable to cause important problems during hot summers. The predatory mite *N. cucumeris* Oud. (Phytoseiidae), have been found naturally colonizing strawberry fields in Latvia (Petrova et al., 2000). *N. cucumeris* is produced on a commercial basis

in Latvia, and, according to our experience, introduction of this species proved to be highly effective to control *P. pallidus* and *T. urticae* on field-grown strawberry (Petrova et al., 2002).

The aim of this study was to extend knowledge of *Neoseiulus cucumeris* and its role in regulation of *P. pallidus* populations on strawberry runner plants before their planting in the production fields.

Materials and Methods

The study was conducted in 2001 at the Institute of Biology, University of Latvia, and consisted of two experiments done under laboratory and outdoor conditions. Runners of the strawberry cultivar 'Honeoye' were used for this study. In the end of July each runner plant was planted separately in soil substrate that was filled in a soft plastic pot (volume of substrate – 120 ml^3). Then 72 runner plants were placed in 6 wooden boxes (flats) (50 × 30 cm) filled with soil substrate and kept in outdoor conditions till the beginning of experiments.

Both the strawberry mites and the predatory mites were counted on all folded and unfolded leaves of all strawberry runner plants in control and experiment. The living mites, including embryonic stages, were counted using a stereo microscope.

Experiment 1: Influence of *N. cucumeris* on a strawberry mite population in laboratory conditions

The first experiment was carried out in laboratory conditions from 17th to 28th of August. Average temperature was 21°C and RH varied between 70 and 80%. The runners were rooted and on the average had 3 leaves (2 unfold and 1 fold).

72 runner plants were naturally infested by *P. pallidus*. Some individuals of the two-spotted spider mite and naturally occurring phytoseiid mites were found and destroyed. In the beginning of experiment *P. pallidus* population density was in the range from 26 to 737 specimens (including active and embryonic stages) per plant. Infested plants in experiment 1 and control were ranged in 4 groups with different levels of population density (each group included 9 repetitions, numbers of specimens in each group were significantly different at P = 0.05):

A) Plants infested with the pest at a high population density – 507.2 ± 105.5 specimens per plant;
B) Average high population density – 209.7 ± 36.8 specimens per plant;
C) Average low population density – 144.7 ± 10.1 specimens per plant;
D) Low population density – 85.1 ± 32.1 specimens per plant.

Groups of infested plants in control:

A) High population density – 603.3 ± 39.6 specimens per plant;
B) verage high population density - 282.8 ± 44.9 specimens per plant;
C) Average low population – 115.6 ± 4.7 specimens per plant;
D) Low population density – 48.5 ± 4.3 specimens per plant.

A single release of *N. cucumeris* was done with the predator: prey ratio 1: 5 (17th of August). The release included healthy populations of adult and immature (proto- and deutonymphs) *N. cucumeris*. Predatory mites were maintained in wheat bran with flour

mites as food and released using a simple hand operation. The active and embryonic stages of the pest and predatory mites were counted 3 times (1st – before predatory mite release, 2nd and 3rd – after release) during the experiment. The efficiency of *N. cucumeris* was evaluated on the 7th and 10th day after the release.

Experiment 2: Influence of *N. cucumeris* on a strawberry mite population in outdoor conditions

The second experiment was established under outdoor conditions (orchard) from 28th of August to 11th of October. Temperature ranged from 6.6 to 16.7°C in September and from 6 to 14.3°C in the beginning of October (Table 1). In this experiment, we used only 36 runner plants. In the beginning of experiment *P. pallidus* population density was in range from 115 to 1152 specimens (including active and embryonic stages) per plant. Therefore plants used in experiment 2 were ranged in 4 groups (numbers of specimens in each group were significantly different at P = 0.05):

A) Plants infested with the pest at a high population density – 1047.0 ± 64.5 specimens per plant;
B) Average high population density – 734.4 ± 36.8 specimens per plant;
C) Average low population density – 470.3 ± 4.1 specimens per plant;
D) Low population density – 174.9 ± 60.0 specimens per plant.

A single release of *N. cucumeris* was done with the predator: prey ratio 1:10 (27th of August). Both strawberry mite and predatory mite populations were estimated during 6 weeks.

Results

Experiment 1: Influence of *N. cucumeris* on the strawberry mite population in laboratory conditions

After a single release of the predatory mite *N. cucumeris* with the predator: prey ratio 1: 5, we found that the pest population density decreased 153 times in **A** group. During seven days after the release of *N. cucumeris,* the strawberry mite's *P. pallidus* population was entirely destroyed in groups **B**, **C** and **D** (Figure 1).

In the 24th of August, there were 4 runner plants in group **A;** at an average, there were 4.5 prey females and 16 preimaginal prey stages per plant. In control, prey population density increased significantly. During 7 days it increased 1.6 times in group **A**; 3.0 times in group **B**; 4.7 times in group **C**; and 10.3 times in group **D,** compared to the groups, in which *N. cucumeris* were released (Figure 1).

Thus, the pest population density decreased for 99.8 ± 0.9% on the 7th day and for 100% on the10th day after *N. cucumeris* release.

Experiment 2: Influence of *N. cucumeris* on the strawberry mite population in outdoor conditions

Studies in outdoor conditions were performed in autumn; the results were given in Figure 2. The predatory mite *N. cucumeris* was released on strawberry runner plants infested by strawberry mites with different population densities (Figure 2). It was found that during the first week of the experiment the number of active strawberry mites and

their eggs in groups **A, B, C** and **D** was reduced by *N. cucumeris* 2.9, 3.9, 6.9 and 6.1 times, respectively. During two weeks the population of strawberry mites was reduced 6.4 times in group **A,** and 15.7 times in group **D**.

The efficiency of predatory mites, however, was much higher on plants in groups **B** and **C,** where the number of strawberry mites was reduced 29.9 and 40.1 times, respectively (Table 1).

Significantly greater numbers of prey were consumed in higher density prey patches compared to low density patches. The number of strawberry mites (all stages) reduced progressively according to the level of plant infestation 1 week and 2 weeks after the introduction of *N. cucumeris*.

After the 3rd week of the experiment, predatory mites reduced the number of *P. pallidus* practically down to zero in groups **C**, and **D,** excepting groups **A** and **B**. Only after 4th week strawberry mites were consumed entirely also in group **B** and after 5th week in all group (Figure 2).

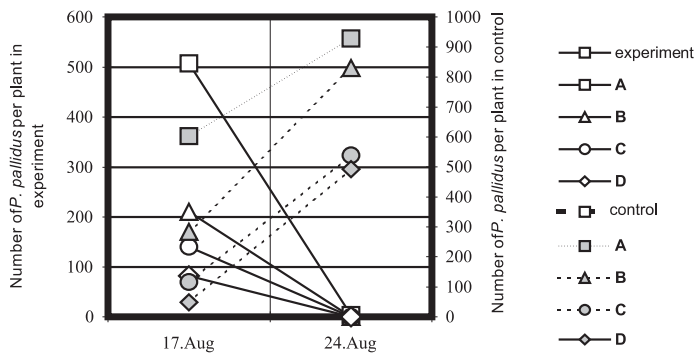
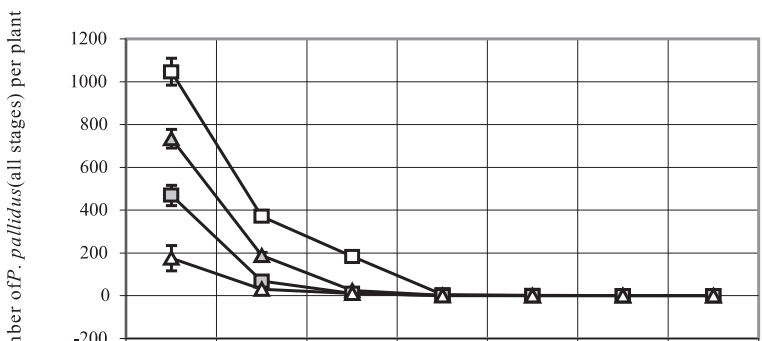


Figure 1. Average numbers of *P. pallidus* (all stages per plant) in experiment and in control after the release of *N. cucumeris* (predator: prey ratio 1: 5) (experiment 1).



	24.Aug	03.Sep	12.Sep	20.Sep	27.Sep	4. Oct	11. Oct
A	1047	372	184	4	2	0	0
B	734	190	25	2	0	0	0
C	470	69	12	0	0	0	0
D	175	30	12	0	0	0	0

Figure 2. Average numbers of *P. pallidus* (all stages per plant) before and after the release of *N. cucumeris* (predator: prey ratio 1: 10) (experiment 2).

Thus, we obtained relatively high efficiency of *N. cucumeris* in all experimental groups already after the first week: from 64.6 ± 9.1 % to 83.1 ± 3.0% (Table 1). After the second week, the efficiency ranged from 82.7 ± 5.8% to 92.4 ± 3.8%. After the 3rd week from beginning of experiment, we observed the following efficiency: 99.1 ± 1.5% in group **A,** 99.8 ± 0.5% in group **B,** and 100% in groups **C** and **D**. Overall efficiency of *N. cucumeris* achieved after the 1st, 2nd, 3rd, 4th and 5th week from its single release – 76.3 ± 10.4%, 88.9 ± 7.6%, 99.8 ± 0.8%, 99.9 ± 0.1% and 100%, respectively (Table 1).

Very high efficiency was observed in spite of the lowering temperature in autumn (1st of September – 11th of October) (max. temperature 20°C, min. – 2.5°C). Finally, the average pest population density in outdoor conditions decreased 5.0 times during the1st week, 23.0 times during the 2nd week, and 52.9 times during the 3rd week after *N. cucumeris* release.

Table 2 shows how the population of *N. cucumeris* and predator: prey ratio varied during the outdoor experiment. Although predatory mites were released in the beginning of experiment with theoretically predator: prey ratio 1:10, but after the 1st week the ratio was changed to 1: 22 into group with higher plant infestation (**A**). So after the 1st week only in group **B** ratio predator: prey (1:10) was equal to theoretical ratio and in groups C and D it was increased to 1: 5 and 1: 3. After the 2nd week the predator: prey ratio varied from 1: 7 in group **A** to 2: 1 in group **D** with low pest population density. The predator: prey ratio gradually increased in all groups during the 3rd, 4th, 5th and 6th weeks, particularly so in groups **A**, **B** and **D**.

Active stages of *N. cucumeris* were counted during entire experiment; the obtained numbers did not vary significantly in groups **A**, **B** and **C**. Significant differences in predator's numbers were found only in the group with low population density (**D**) after the first and the second week.

Discussion

It was established that climatic conditions caused significant differences between both experiments: in laboratory there is little variation in temperature and RH, but in outdoor conditions these parameters can change significantly and very quickly within a period of six weeks. Thus better results were obtained in the laboratory with higher daily temperature and at predator: prey - ratio 1:5.

Positive results in the control of strawberry mite with *N. cucumeris* on newly planted fields were obtained also in Finland (Tuovinen, 2002). It is known that hot-water treatment of strawberry runners (44-46°C) can also kill all strawberry adult mites (Hellqvist, 2002), but this treatment has not achieved 100% mortality of all tarsonemid mites' life stages. *N. cucumeris* has been recorded as a predator of all strawberry mite life stages (Fitzgerald and Easterbrook, 2003), therefore we consider that the use of *N. cucumeris* on strawberry runners before their planting is economically reasonable and technically easier than Hellqvist's method.

Conclusions

Good results were obtained in both experiments with introduction *N. cucumeris* on strawberry runners: under constant laboratory conditions in August and under variable

outdoor conditions in September and in the first ten-day period of October.

Positive results obtained in our study of biological control of the strawberry mite *P. pallidus* using the predatory mite *N. cucumeris* show that this predatory mite can be recommended for the control of the strawberry mite on the runner plants before their planting in field.

The use of *N. cucumeris* on runner plants is economically reasonable, especially in newly planted fields, and in such manner, healthy planting material gives the possibility to exclude the use of any acaricides against *P. pallidus.*

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Table 1. Average weekly outdoor temperature (°C) and efficiency (%) of *N. cucumeris* (Experiment 2)

After	Tempera-ture, °C	Mean ± SD efficiency, %				
	mean ± SD	A	B	C	D	Overall
1st week	13.6 ± 1.7	63.2 ± 9.4 (b)	73.4 ± 5.3 (b)	85.4 ± 2.0 (b)	83.1 ± 3.0 (b)	76.2 ± 10.4 (b)
2nd week	12.7 ± 1.8	82.8 ± 5.5 (b)	96.6 ± 0.6 (a)	97.5 ± 0.3 (a)	92.4 ± 3.8 (b)	88.8 ± 7.6 (ab)
3rd week	13.5 ± 2.2	99.2 ± 1.4 (a)	99.8 ± 0.5 (a)	100 ± 0 (a)	100 ± 0 (a)	99.8 ± 0.8 (a)
4th week	10.1 ± 3.9	99.9 ± 0.1 (a)	100 ± 0 (a)	100 ± 0 (a)	100 ± 0 (a)	99.9 ± 0.1 (a)
5th week	9.4 ± 3.4	100 ± 0 (a)	100 ± 0 (a)	100 ± 0 (a)	100 ± 0 (a)	100 ± 0 (a)
6th week	11.7 ± 1.9	100 ± 0 (a)	100 ± 0 (a)	100 ± 0 (a)	100 ± 0 (a)	100 ± 0 (a)

[a] In each column, means with different letters differed significantly ($P < 0.05$)

Table 2. Average number of predatory mites *N. cucumeris* (only active stages per plant) in groups (A, B, C, D) and the predator: prey ratio during experiment 2

Data	Mean ± SD number of *N. cucumeris* per plant				Predator : prey ratio			
	A	B	C	D	A	B	C	D
03. Sep	16.9 ± 5.9 (a)	18.2 ± 8.5 (a)	13.0 ± 4.2 (a)	9.8 ± 3.6 (b)	1 : 22	1 : 10	1 : 5	1 : 3
12. Sep	24.5 ± 6.8 (a)	36.5 ± 13.2 (a)	18.9 ± 6.4 (a)	31.2 ± 5.0 (a)	1 : 7	1 : 5	1 : 1	2 : 1
20. Sep	11.2 ± 2.4 (a)	12.1 ± 4.1 (a)	9.5 ± 4.0 (a)	16.2 ± 4.7 (ab)	3 : 1	6 : 1	9 : 0	16 : 0
27. Sep	9.4 ± 5.9 (a)	17.3 ± 7.2 (a)	15.0 ± 6.1 (a)	17.0 ± 8.1 (ab)	2 : 1	17 : 0	15 : 0	17 : 0
4. Oct	5.9 ± 3.7 (a)	12.3 ± 8.1 (a)	12.1 ± 1.6 (a)	20.3 ± 9.9 (ab)	6 : 0	12 : 0	12 : 0	20 : 0
11. Oct	7.4 ± 6.9 (a)	15.1 ± 7.8 (a)	16.3 ± 7.6 (a)	20.4 ± 12 (ab)	7 : 0	15 : 0	16 : 0	20 : 0

[a] In each column, means with different letters differed significantly ($P < 0.05$)

Part E

"FRUIT AND BERRY STORAGE, QUALITY AND BIOCHEMICAL STUDIES"

INVESTIGATION OF THE BIOCHEMICAL COMPOSITION OF CHERRIES IN LATVIA

Silvija RUISA, Inta KRASNOVA, Daina FELDMANE

Latvia State Institute of Fruit-Growing
Graudu 1, Dobele LV-3701, Latvia
e-mail: Silvija.Ruisa@lvai.lv

Abstract

Sweet and sour cherries are favorite fruit crops in Latvia. Recent research in Europe has proven that cherries are a valuable natural source of some bioactive compounds important in the human health preservation, including phenolic compounds, vitamins and minerals. The aim of the investigation was to determine the biochemical composition of sweet and sour cherry cultivars more widely grown in Latvia. Fresh and frozen fruits of 12 sweet cherry and 2 sour cherry cultivars were tested for the composition of soluble solids, total content of organic acids, anthocyans and phenolic compounds during 2005 – 2007 in Latvia State Institute of Fruit-Growing.

The biochemical composition of fresh and frozen sweet and sour cherry fruits varied depending on the year of growing and cultivar. The content of soluble solids in sweet cherry fruits varied from 14.4 to 18.1 % depending on the cultivar; in sour cherry fruits – from 10.6 to 17.9 %. The composition of total organic acids in sweet cherry cultivars changed from 0.44 to 1.1 %; in sour cherry cultivars – from 1.3 to 3.0 %.

Depending on the cultivar 13.2 – 126.7 mg·100g^{-1} of anthocyans were found in sweet cherries, 43.3 – 120.7 mg·100g^{-1} – in sour cherry cultivars. The total composition of phenolic compounds varied from 93.4 to 437.8 mg·100g^{-1}. in sweet cherries and from 439.0 to 637.2 mg·100g^{-1} in sour cherries.

The content of phenolic compounds in frozen cherries reduced significantly depending on the year of growing and cultivar. The highest composition of phenolic compounds was found in sour cherry cultivar 'Tamaris': 637.2 mg·100g^{-1}.

Key words: cherries, soluble solids, organic acids, anthocyans, phenolic compounds

Introduction

Cherries both sweet and sour ones are favorite fruit crops in Latvia. Recent research in Europe (Veres and Dietrich, 2005; Will et al., 2005) has proven that cherries are a valuable natural source of some bioactive compounds important in the human health preservation, including phenolic compounds, vitamins and minerals.

Since soluble solids content is closely related to fruit colour and firmness through the season, the suggestion was that soluble solids content is a useful indicator of optimal harvest maturity for this cultivar (Webster, Looney, 1996).

Sugar content has an essential role in determining the taste and quality of fruits. Total sugar content varies from 12 to 15.4 % for sweet cherry cultivars grown in Latvia. The composition of organic acids is other important criterion for estimation of fruit quality. The main organic acid in cherries is malic acid: about 85 % (Webster, Looney, 1996). Fruits contain also citric acid, isocitric acid, quinic acid.

For sweet cherries the total content of acids varied from 0.3 to 1.0 % (Jaama, 1992; Parfenova, 1998; Janes, Pae, 1999; Kolesnikova, 2003). Content of organic acids in sour cherries changed from 0.7 to 3.0% (Kolesnikova, 2003). Relationship among total sugar and acid content for sweet cherry cultivars grown in Latvia varies from 1.4 to 2.1. Vitamin C is one of the most important antioxidants. The content of vitamin C in cherries is very variable: it changed depending on harvest maturity, cultivar, weather and growing conditions.

Sweet cherry cultivars 'Kristiina', 'Polli Rubiin' and 'Drogan's Gelbe Knorpelkirsche' contained 12.7 – 13 mg% vitamin C (Jaama, 1992), but 'Meelika' – 19 mg% (Janes, 1999) in Estonia, whereas sweet cherry cultivars growing in Crimea contained 5.1 – 10 mg% (Parfenova, 1998). However, the composition of vitamin C varied from 8.8 to 26.2 mg% in Bryansk, Russia (Kanshina, Astahov, 2000).

Phenolic compounds are very important due to their positive effect on human body. In Germany sour cherry juices and wines were produced from 5 different cultivars: 'Schattenmorelle', 'Gerema', 'Ungarishe Traubige', 'Cigany and 'Stevnsbaer Brigitte'. In the sum, 651-1693 $mg \cdot L^{-1}$ of polyphenols were found in juices and wines. The high polyphenol concentrations were responsible for the high antioxidative capacities of the products. The fermentation process did not affect the amounts of polyphenols significantly (Will and Dietrich, 2005).

The antioxidant value of 100 g sour cherry is equivalent to 311 mg of vitamin C (Veres et al., 2005).

Cherry juice fresh or boiled for 10 minutes is very effective against the harmful effect of mutagens. It is suggested that this effect is provided by flavonoides in cherries (Feucht et al., 2001).

The composition of bioactive compounds is depending on cultivar, harvest maturity, growing conditions and climate.

The aim of this investigation is to determine the bioactive compounds: soluble solids, total acid content, total anthocyans and total phenolic compounds content of fresh and frozen sweet and sour cherry cultivars after 6 month storage.

Material and methods

The fruits of 12 following sweet cherry and 2 sour cherry cultivars more widely grown in Latvia were tested for their composition of bioactive compounds.

The biochemical content: soluble solids, organic acids, anthocyans, phenolic compounds of fresh and frozen cherry fruits after 6 month storage were determined in the Laboratory of Biochemistry of the Latvia State Institute of Fruit-Growing during 2005 – 2007. Each analysis was performed in 3 replications. Fruits were harvested depending on the maturity.

The following characteristics were determined for sweet and sour cherry cultivars:

- The content of soluble solids (^{o}Brix) was determined at temperature 20 °C with a digital refractometer ATAGO N20 (deviation of measuring instrument face value ±0.1%) (ISO 2173:2003);
- The content of total acids (%) was determined by titrating with 0.1N NaOH (ISO 750 – 1998);

- The content of anthocyans (mg $100g^{-1}$) was determined with the method of spectrometry, by using a spectrometer UV-1650-PC at wave length 535 nm (Moor et al., 2005).
- The total content of phenols (mg $100g^{-1}$) was determined with the method of spectrometry, by using a spectrometer UV-1650-PC at wave length 765 nm (Singleton et al., 1999).

Fruits from 13 cultivars were tested when analyzing the influence of the growing year. Fruits were analyzed for 3 years.

Data were statistically processed by using SPSS for Windows and MS Excel. Two-factor variance analysis (Scheffe test) was applied for estimating the effect of the genotypes and the year, significance level at $p_{crit} = 0.05$.

Meteorological data of the years 2005 – 2007 are shown on Figure 1.

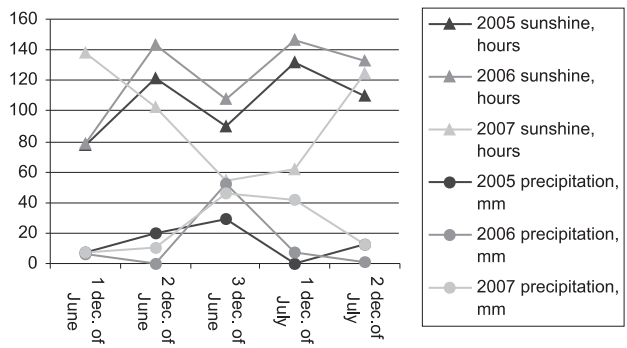

Figure 1. Meteorological data in the years of 2005- 2007

Results and discussion

The composition of bioactive compounds in fresh and frozen fruits of sweet and sour cherry cultivars was influenced by the year of growing and by the cultivar. The changes depending on the year of growing are shown in Figures 2 – 3.

Soluble solids are one of the quality parameters and maturity indicator of cherry fruits. They characterize the content of total sugars, acids, vitamins, minerals and other substances present in fruits.

The average content of soluble solids changed from 16.4 to 16.9 °Brix in fresh sweet cherry fruits and from 14.3 to 15.8 °Brix in fresh sour cherry fruits investigated (Figure 2). It varied depending on the year of growing ($p<0.05$). The changes of the average content of soluble solids were insignificant in 2005 (16.6 °Brix) and in 2006 (16.7 °Brix). However, the variations in 2007 were significant: the average content of soluble solids was 16.1 °Brix.

Similar results were obtained when frozen cherries after 6 months of storage were analyzed: the content of soluble solids, if compare to the years of 2005 and 2006, reduced in 2007. In general, the content of soluble solids in frozen cherries after 6 months of storage reduced insignificantly – for 0.45 °Brix.

The effect of the year of growing on the total content of acids in the fresh and frozen fruits is shown in Figure 2. The average total acidity of fresh sweet cherry fruits varied

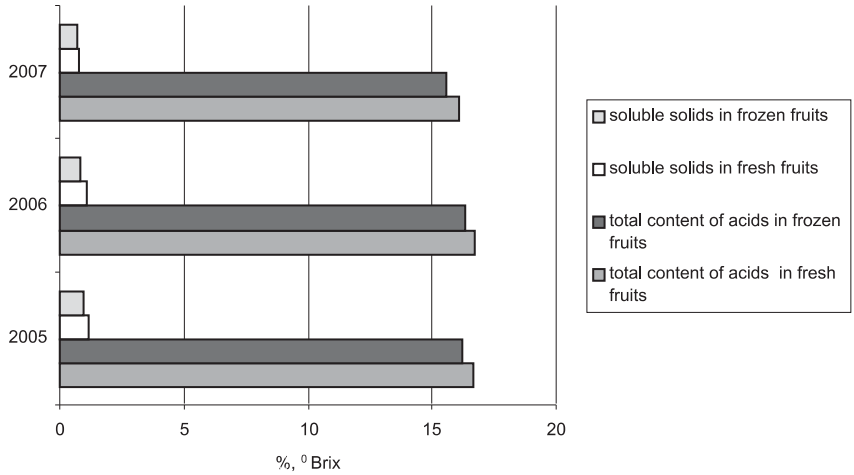

Figure 2. The content of soluble solids and total acids of fresh and frozen cherry fruits (the average of years 2005 – 2007).

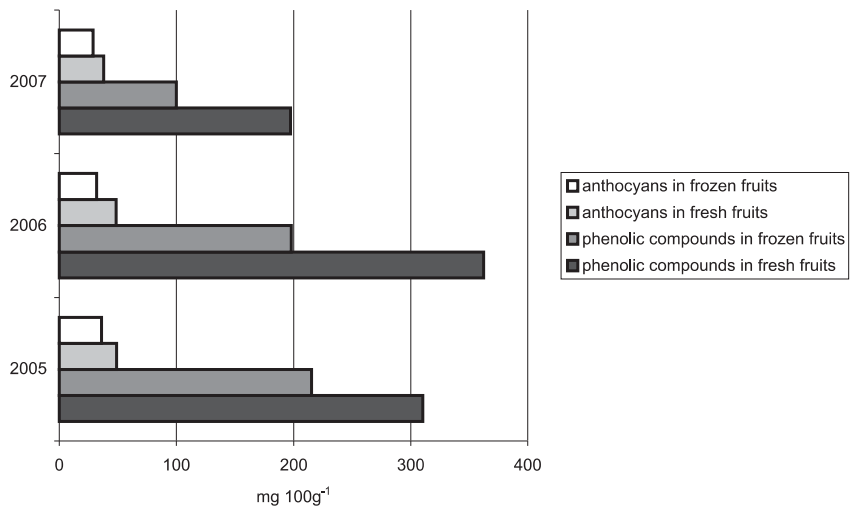

Figure 3. The content of total anthocyans and total phenolics in fresh and frozen cherry fruits (the average of years 2005 – 2007).

from 0.6 to 0.9 % and from 1.6 to 2.3 % in fresh sour cherries depending on the year of growing and cultivar ($p<0.05$). Like the content of soluble solids the total composition of acids reduced significantly in 2007, comparing with the same in 2005 and 2006. The total content of acids in the frozen fruits after 6 months of storage reduced insignificantly – for 0.05 – 0.26 %.

Fruits not only provide us with important antioxidant vitamins (e.g. vitamin C, vitamin E and carotene – provitamin A), but also phytochemicals or a complex mixture of other natural substances with antioxidant capacity – such as anthocyans that have high antioxidant activity and antidiabetic properties.

Among phytochemicals, polyphenols deserve a special attention due to their free radical scavenging activities. Phenolic compounds have multiple biological effects, including antioxidant activity, which,as mentioned in the lot of publications play a preventive role in the development of cancer and heart disease.

The average total content of anthocyans in fresh sweet cherry fruits varied from 35.1 mg 100 g^{-1} to 43.9 mg 100 g^{-1} and in fresh sour cherry fruits from 53.6 mg 100 g^{-1} to 87.8 mg 100 g^{-1}. Changes of the content of anthocyans depending on the year of growing are shown in Figure 3: the variations of anthocyans in fresh fruits were insignificant.

The differences in the content of anthocyans depending on the year of harvesting in frozen cherries after 6 months of storage were insignificant as well.

The average total content of phenolic compounds changed from 151.0 mg 100 g^{-1} to 307.2 mg 100 g^{-1} in fresh sweet cherry fruits and from 453.8 mg 100 g^{-1} to 585.7 mg 100 g^{-1} in sour cherry fruits. Differences of the content of phenolic compounds influenced by the year of growing are shown in Figure 3. The variations of the average total phenolic compounds were insignificant in the years of 2005 (22.4 mg 100 g^{-1}) and 2006 (74.26 mg 100 g^{-1}). However, the changes in 2007 were significant: 90.6 mg 100 g^{-1}. The results were similar with frozen cherries. So, the content of total phenolic compounds reduced significantly, from 280.9 mg 100 g^{-1} to 157.1 mg 100g^{-1}.

The content of soluble solids, total acids and phenolic compounds were reduced in 2007, if compare to the years of 2005 and 2006. It probably could be explained by the less sunshine hours and more rainy days during fruit ripening (Figure 1).

The content of soluble solids, total acids, anthocyans and phenolic compounds varied depending on the cultivar; these variations are shown in Figures 2–3.

The highest content of soluble solids was ascertained in fresh fruits of sweet cherry cultivars: 'Bryanskaya 3-36', 'Krupnoplodnaya', 'Meelika', 'Indra', 'Aija', 'Revna': from 16.9 to 17.8 ^{o}Brix and in sour cherry cultivar 'Latvijas Zemais' – 16.8 ^{o}Brix. The content of soluble solids in frozen fruits depending on cultivar reduced insignificantly.

The highest content of organic acids was detected in fresh and frozen sour cherry fruits, but the lowest in sweet cherries 'Bryanskaya 3-36', 'Revna', 'Paula' – from 0.4 to 0.6 %.

The highest composition of anthocyans was found in the fresh fruits of sweet cherry cultivars: 'Meelika' (117 mg 100 g^{-1}), 'Indra' (56.6 mg 100 g^{-1}) and in sour cherry cultivar 'Tamaris' (89.1 mg 100 g^{-1}). The content of anthocyans in frozen cherries reduced for all cultivars studied: from 5.6 to 40 %.

In another research with raspberries it was found that total extraction of anthocyans during freezing for the some raspberry cultivars can be reduced from 19 to 9 %, but for the others it can be even increased and it could be explained by the better extraction from fruit cells (Ancos et al., 2000a).

The highest content of phenolic compounds was detected in the fresh fruits of sour cherry cultivars: 'Tamaris' (580.7 mg 100 g^{-1}) and 'Latvijas Zemais' (473.4 mg 100 g^{-1}) and sweet cherry cultivars 'Meelika' (380.2 mg 100 g^{-1}) and 'Indra' (307.7 mg 100 g^{-1}). The content of phenolic compounds in frozen cherries reduced for all cultivars from 20.2 to 47 %. In study with raspberries no significant changes in total phenolic compounds content of the four raspberry cultivars were found after freezing. There were slight

increases of 12 and 5 % of the total phenolic compounds contents in some cultivars and 13 and 5 % decreases in the total phenolics compounds in others (Ancos et al., 2000).

Due to a high content of phenolic compounds sour cherry cultivar 'Tamaris', sweet cherry cultivars 'Meelika' and 'Indra' may be valued as having a high antioxidant activity.

Conclusions

1. The biochemical composition of fresh and frozen sweet and sour cherry fruits varied depending on the year of growing and cultivar.
2. The changes of the content of soluble solids, total acids and phenolic compounds depending on the year were significant.
3. The content of anthocyans in fresh and frozen fruits depending on the year of growing differed insignificantly.
4. The highest content of phenolic compounds was found in the fresh fruits of sour cherry cultivars: 'Tamaris' (580.7 mg 100 g^{-1}) and sweet cherry cultivars 'Meelika' (380.2 mg 100 g^{-1}) and 'Indra' (307.7 mg 100 g^{-1}).
5. The content of soluble solids, total acids and anthocyans in frozen cherries reduced insignificantly depending on the year of growing and cultivar.
6. The content of phenolic compounds in frozen cherries reduced significantly depending on the year of growing and cultivar.

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Table 1. Cherry cultivars analyzed in the investigation

Cultivar	Country of origin	Fruit colour	Fruit mass, g
Sweet cherries			
Aija	Latvia	Light red	4 – 4.5
Bryanskaya 3-36	Russia	Dark red	4.5 - 5
Gronkavaya	Byelorussia	Dark red	4 – 4.5
Indra	Latvia	Dark red	3.5 - 4
Iputj	Russia	Dark red	5.5 - 6
Krupnoplodnaya	Ukraine	Dark red	9 - 10
Meelika	Estonia	Dark red	3 – 3.5
Ovstuzhenka	Russia	Dark red	4 - 5
Paula	Latvia	Yellow	6 – 6.5
Radica	Russia	Dark red	4 - 5
Revna	Russia	Dark red	4.5 - 5
Tiytchevka	Russia	Dark red	5 – 5.5
Sour cherries			
Latvijas Zemais	Latvia	Dark red	3 – 3.5
Tamaris	Russia	Dark red	4 - 5

RESEARCH ON ANTIOXIDANT ACTIVITY OF BERRIES GROWN IN LATVIA

Dalija SEGLIŅA, Inta KRASNOVA, Silvija RUISA, Sarmīte STRAUTIŅA, Gunta HEIDEMANE

Latvia State Institute of Fruit-Growing
Graudu 1, Dobele LV-3701, Latvia
e-mail: dalija.seglina@lvai.lv

Abstract

Antioxidants are important health improving compounds what scavenge free radicals. There are a lot of evidences that uncontrolled free radical activity has been linked to cancer, heart disease, Alzheimer's disease, Parkinson's disease, etc. Berries have some of the highest antioxidant levels of any fruits.

The aim of this research was to determine the biochemical content of several berry cultivars and genotypes. The best cultivars will be recommended for commercial growing, breeding and processing. In total, 86 genotypes of black currants, 21 genotypes of raspberries and 6 most popular cultivars of sea buckthorn were examined. The research was done during 3 years. The chemical composition of berries was evaluated and total content of anthocyanins, vitamin C, E, phenolic compounds and radical scavenging activity (DPPH and ABTS methods used) were determined. The average biochemical composition of sea buckthorn cultivars was characterized by content of vitamin C – 84.9 mg 100 g^{-1}, vitamin E – 23.2 mg 100 g^{-1}, total carotenoids – 14.5 mg 100 g^{-1}, total phenolic compounds – 126.1 mg 100 g^{-1}. The highest content of mentioned biologically active compounds was found for cultivars 'Trofimovskaya' and 'Podarok Sadu'.

The content of phenolic compounds in black currant cultivars ranged from 438.5 to 306.8 mg 100g^{-1} and the same in raspberry cultivars from 372.62 to 222.21 mg 100 g^{-1}. The content of vitamin C varied from 255.0 to 107.7 mg 100 g^{-1}in black currants, but only from 40.2 to 28.7 mg 100 g^{-1} in raspberries. The antioxidant activity varied depending on the method. The radical scavenging activity detected by ABTS method and expressed as the percentage of inhibition was 41.9 – 57.2% for black currant and 44.2 – 52.9% for raspberries, and 34.5 – 46.4% for black currant and 42.2 – 56.9% for raspberries, consequently detected by DPPH.

Key words: antiradical activity, black currant, raspberries, sea buckthorn

Introduction

Fruits, berries and their processing products reduce the risk of diseases due to favorable impact on body functions. The tendency to replace synthetic antioxidants by organic ones for food products stabilization is growing during last years, since some of synthetic antioxidants had shown a carcinogenic effect (Andersen et al., 2004). Flavonoids are the greatest group of polyphenols having antioxidative characteristics found in plant kingdom. Black currants, raspberries and sea buckthorn contain remarkable amount of flavonoids, ensuring stability of vitamin C in berries (Constantino et al., 1992; Prokkola et al., 2003).

It is mentioned that flavonoids, phenolic acids and anthocyans as antioxidants influence health favorably (Puupponen-Pimiä et al., 2001). Free radical scavenging

activity is depending on the content of total polyphenolics including the content of anthocyans (Constantino et al., 1994). Several researchers have concluded that antoxidative capacity is higher in darker berries (Deighton et al., 2002; Courtney and Rui, 2002).

The composition of biologically active compounds in fruits and berries is depending not only on the cultivar, but also on the growing place, meteorological conditions and degree of maturity.

The content of polyphenols in black currants (expressed in gallic acid equivalents) can reach 1160 mg 100 g^{-1}, of anthocyans – from 110 to 430 mg 100 g^{-1} (calculated as delphinidin) (Constantino et al., 1992; Constantino et al., 1994), and vitamin C – from 50 to 400 mg 100 g^{-1} (Lee and Kader, 2000; Lister et al., 2002). Cyanidin- and delphinidin-3 glycosides and ruthinosides are the most important anthocyans presented in black currants. Several West European cultivars contain cyanidin as main anthocyans, but Scandinavian cultivars, as 'Ben Alder' – mostly delphynidin (Kampuse, 2006).

Sea buckthorn fruits are rich in biologically active compounds, including vitamin C and E, carotenoids, unsaturated fatty acids, free amino acids and others (Korovina and Fefelov, 2005; Novruzov, 2005; Jamyansan and Badgaa, 2005; Antonelli et al., 2005). It is found that sea buckthorn juice has a high medicinal and nutritive value for health improving (Rosh et al., 2003; Zeb, 2004; Zeb, 2004 a). As it is found, vitamin C can reach 373 mg 100 g^{-1} (Antonelli et al., 2005) in European sea buckthorn species *H. rhamnoides*. The content of carotenoids varies from 0.5 to 65.5 mg 100 g^{-1} (Aksenova and Dolgacheva, 2003; Novruzov, 2005). The content of vitamin E in fresh sea buckthorn fruits is different: from 1 to 36 mg 100 g^{-1} (Kallio et al., 2002; Singh, 2005). It was reported that total content of flavonoids in fresh fruits can reach 552.0 mg 100 g^{-1} (Novruzov, 2005).

The raspberry anthocyans cyanidin-3 and delphinidin-3 glycosides as promoters of insulin secretion cause a special attention due to increasing problems of diabetes. The total content of anthocyans in red raspberries varies from 20 to 65 mg 100 g^{-1} in light colored berries, however in dark colored berries the concentration is 90 – 510 mg 100 g^{-1}, but in black raspberries even to 536 mg 100 g^{-1} (Shahidi and Naczk, 1995; McGhie et al., 2002; Moyer et al., 2002). Due to the high content of polyphenols: 280 – 360 mg 100 g^{-1} (Constantino et al., 1992), raspberries have a strong antimicrobial activity if compare to the other berries grown in northern countries, as bilberries, cloudberries and strawberries (Puupponen-Pimiä et al., 2001). Raspberries comparing to black currants do not contain high amounts of vitamin C: the average content is about 30 mg 100 g^{-1}.

It is recommended to use different methods for determination of antiradical activity of fruits and berries. The methods most often used for determination of antiradical activity are spectrophotometric assays in model systems containing $ABTS^{\bullet+}$ and $DPPH^{\bullet}$ free radicals. It is found that the results of radical scavenging activity obtained by DPPH method exactly correlate with content of polyphenolic compounds in fruits and berries (Kaur and Geetha, 2006; Stratil et al., 2006).

The aim of the present research is to determine the composition and content of the most important biologically active compounds of black currants, raspberries and sea buckthorn and their antiradical activity.

Material and methods

The object of the research – fruits of sea buckthorn (*Hippophae rhamnoides* L.) cultivars 'Avgustinka', 'Prozrachnaya', 'Botanicheskaya Lubitelskaya', Luchistaya', 'Trofimovskaya' and 'Podarok Sadu', widely grown in Latvia, was harvested at SIA „Baltplant", Dobele region in 2004 and 2005; raspberries cultivars 'Ottawa', 'Skromnitsa', 'Meteor', 'Norna' and *Rubus Idaeus* L. and black currant cultivars 'Joninai', 'Vernisazh', 'Őjebyn' and 'Titania' was harvested in the Latvia State Institute of Fruit-Growing.

Fruits and berries were frozen in a freezer „PORKKA BF 710" at the temperature –25 ± 1 °C. Frozen fruits and berries were packed in polypropylene bags (1–1.5 kg in each) and stored in a low-temperature chamber „VTK 201 V" at the temperature –18 ± 1 °C for three months.

The following biochemical characteristics were determined:

- The content of ascorbic acid (vitamin C) (mg $100g^{-1}$ was determined by the iodine method (Moor et al., 2005);
- The total content of phenols (mg $100g^{-1}$) was determined by the spectrophptometric Folin-Ciocalteu method using a spectrometer UV-1650-PC at wave length 765 nm (Singleton et al., 1999);
- The content of carotenoids and vitamin E in sea buckthorn samples was determined by a modified method and extraction was carried out with petroleum benzine. The same solvent was used for the determination both carotenoids and vitamin E (Seglina, 2007).
- The total content of anthocyanins (mg $100g^{-1}$) was determined by the conventional method by using a spectrometer UV-1650-PC at wave length 535 nm (Moor et al., 2005);
- Antiradical activity for raspberry and black currant was determined by ABTS [2,2'-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt] and DPPH (2,2'-diphenyl-1-picrylhydrazyl) (Miliauskas et al., 2004). Radical scavenging activity was calculated by the following formula:

$$\% \, Inhibition = [(A_B - A_A)/A_B] \times 100,$$

where: A_B – absorption of blank sample (t = 0 min.);
A_A – absorption of tested extract solution (r = 15 min.).

Data were statistically processed by using SPSS for Windows and MS Excel. One-factor variance analysis (Scheffe test) was applied for estimating the effect of the cultivar and the year, significance level at $p_{crit} = 0.05$.

Results and discussion

Demands for organic food including fresh fruits and their processing products are growing during last years. Fruits of sea buckthorn (*Hippophae rhamnoides* L.) are one of the most suitable raw materials for production of healthy food because of content of large amounts of biologically active compounds important for human body.

The average values (for harvest of 2004–2005) of the chemical composition of the analyzed frozen sea buckthorn fruits are given in Table 1.

High content of vitamin C is a very characteristic trait of sea buckthorn fruits. The differences in the content of vitamin C of frozen sea buckthorn fruits in the research were significant (p = 0.00). The content of vitamin C in the fruits of cultivars investigated was on average 84.92 mg $100g^{-1}$. The lowest content was found for the cultivar 'Prozrachnaya': 72.55 mg $100g^{-1}$ in average, but the highest one – for the cultivar 'Podarok Sadu' 112.36 mg $100g^{-1}$ in average. Increasing content of vitamin C was observed for all cultivars in 2005, especially for 'Avgustinka', 'Botanicheskaya Lubitelskaya', 'Podarok Sadu' and 'Luchistaya'. It can be explained by the daily temperature in July and August of 2005 (during formation and maturing of berries), which was lower than in 2004. These conditions promoted the formation of vitamin C in fruits.

The content of vitamin E is an important parameter of sea buckthorn fruits. Moreover, their content of vitamin E can be higher than in the other popular oily plants. The highest amount of vitamin E contained the cultivar 'Podarok Sadu' – 32 mg $100g^{-1}$ in average, but the lowest one – 'Luchistaya': 16.76 mg $100g^{-1}$ in average. The content of vitamin E differ significantly depending on cultivar (p = 0.00). The lowest content of vitamin E observed in the fruits of cultivars 'Luchistaya', 'Avgustinka' and 'Botanicheskaya Lubitelskaya' from 16.76 to 17.88 mg $100g^{-1}$ (p = 0.61), but the highest one – in cultivars 'Trofimovskaya' and 'Prozrachnaya' - from 27.48 to 28.64 mg $100g^{-1}$) (p = 0.26). It was observed that the content of vitamin E was higher for some cultivars in 2005 than in 2004 ('Prozrachnaya', 'Podarok Sadu', 'Avgustinka'), but for other cultivars ('Trofimovskaya', 'Luchistaya', 'Botanicheskaya Lubitelskaya') it was lower. The changes in vitamin E may be influenced by the cultivar specific response to temperature and precipitation during growing season.

The content of carotenoids was influenced by meteorological conditions. It has been cleared up (Novruzov, 2005) that an important role during formation of carotenoids play the air temperature, the amount of sunny hours, as well as the amount of cloudy and sunny days during the growing season. The highest content of total carotenoids was determined in the fruits of 'Podarok Sadu' (characteristic red overcolor, 21.35 mg $100g^{-1}$), but the lowest – in the fruits of 'Luchistaya' (characteristic yellow overcolor, 8.75 mg $100g^{-1}$ in average).

The total content of carotenoids in some cultivars, if comparing the yield of year 2004 to year 2005, increased ('Botanicheskaja Lubitelskaya' and 'Prozrachnaya'), but decreased in the fruits of cultivar 'Prozrachnaja'. The data obtained in our research on the content of total carotenoids of the cultivars grown in Latvia are similar to those obtained in Germany (Singh and Mörsel, 2005).

Phenolic compounds are a large group of organic substances and they have an important role in photosynthetic processes. Natural phenolic compounds are divided into several groups, of which the one of larger is flavonoids. The content of total phenolic compounds of the cultivars included in the research was different. The highest content of total phenolic compounds was found in the fruits of the cultivars 'Botanicheskaya Lubitelskaya' and 'Podarok Sadu' (141.7 mg $100g^{-1}$ in average), but the lowest one – 'Prozrachnaya' (105.36 mg $100g^{-1}$ in average). It was observed that content of total phenolic compounds was higher in 2005 (in cultivars 'Prozrachnaya', 'Luchistaya' and 'Podarok Sadu') than in 2004. However, the content of total phenolic compounds in the fruits of the other

cultivars in 2005 was smaller, which may be influenced by their response to the different meteorological conditions during growing season.

Raspberries and black currants characterizes by a high content of phenolic compounds. If compare to black currants (from 307 mg 100 g^{-1}in the berries of cultivar 'Vernisazh' to 422 mg 100 g^{-1}in cultivar 'Öjebyn'), raspberries contain less phenolic compounds (from 228 mg 100 g^{-1}in cultivar 'Skromnitsa' to 366 mg 100 g^{-1}in cultivar 'Norna') (Figure 1). The content of phenolic compounds in raspberries and black currants was not influenced significantly after freezing ($p > 0.05$).

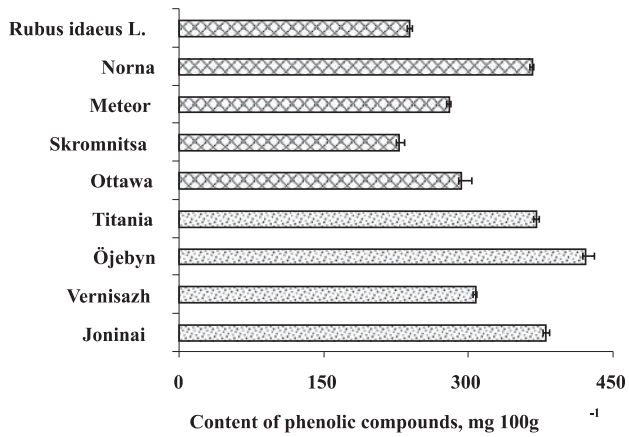

Figure 1. Content of phenolic compounds in berry crops

Berries of black currant contain 8 to 10 times more anthocyans in comparison with raspberries. Significant differences exist among black currant cultivars ($p<0.05$), however among raspberry cultivars investigated differ only cultivar 'Norna' by higher composition of anthocyans. The highest content of anthocyans had black currant cultivar 'Vernisazh': 229.17 mg 100 g^{-1}, among raspberry cultivars – 'Norna': 33.88 mg 100 g^{-1} (Figure 2).

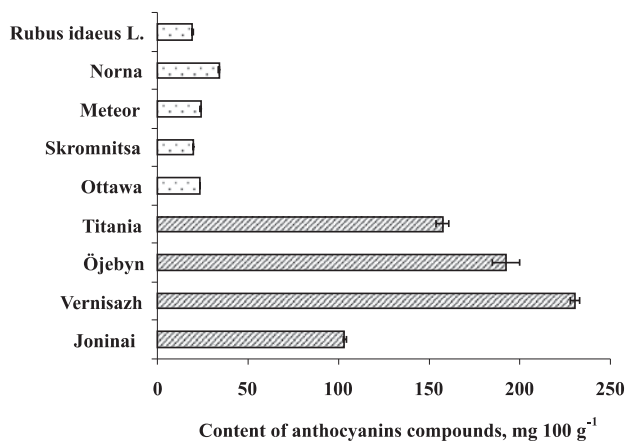

Figure 2. Content of anthocyans in berry crops

The content of vitamin C is not high in raspberries. It varies from 32 mg 100 g^{-1} for cultivar 'Skromnitsa' to 38 mg 100 g^{-1} for cultivar 'Ottawa'. Significant differences among the cultivars were not observed ($p > 0.05$). However, the content of vitamin C in black currant cultivars was higher – from 114 mg 100 g^{-1} in the berries of cultivar 'Öjebyn' to 246 mg 100 g^{-1} for the cultivar 'Joniniai' (Figure 3).

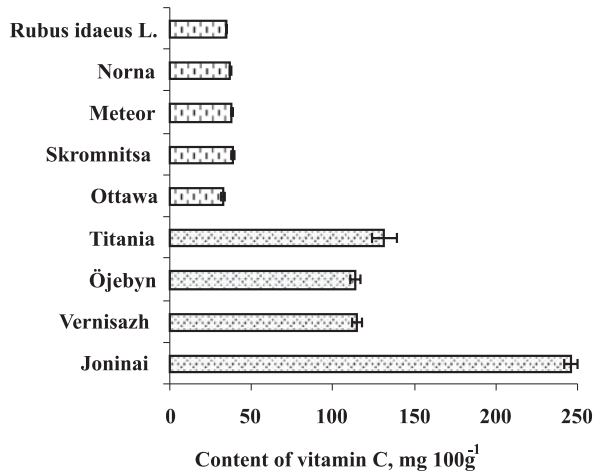

Figure 3. Content of vitamin C in berry crops

Black currant berries are the most important raw material rich in vitamin C useful for processing. It is established that phenolic compounds of black currant stabilize vitamin C during processing. Therefore, by choosing cultivars rich in vitamin C is possible to obtain biologically active processing products.

Using ABTS and DPPH reagents antiradical activity of berries was expressed in %, inhibition. Establishing ARA by ABTS reagent wild raspberries (*Rubus idaeus* L.) showed the higher activity: 40 %, but a little bit lower – cultivars investigated (Figure 4). However, significant differences do not exist. Using DPPH reagent wild raspberries showed the higher activity again: 56 %, but the lower one: berries of the cultivars 'Meteor' and 'Norna'.

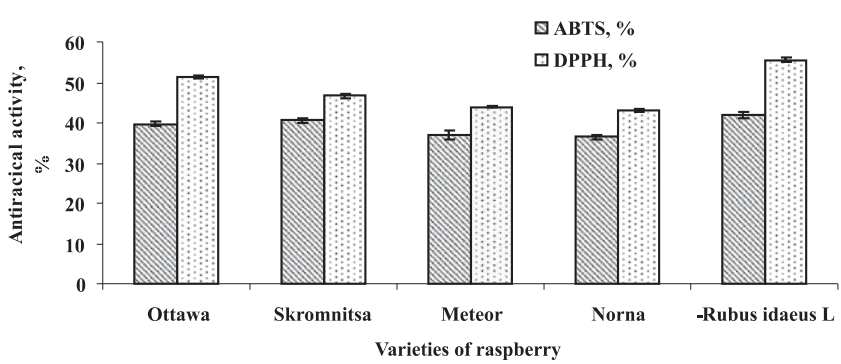

Figure 4. Radical scavenging activity of raspberry fruits by different reagents

Researchers of USA reported that raspberries having the higher content of phenolic compounds show the highest activity. Antiradical activity of raspberries depends on total phenolics including anthocyans and flavonoids ($p < 0.01$) (Kim and Padilla-Zakour, 2004).

Establishing antiradical activity in fresh berries by ABTS reagent according to analysis of regression it can be concluded that the influence of anthocyans is significant ($p = 0.04$).

Evaluating the influence of biochemical parameters (total phenolic compounds, anthocyans and vitamin C) on antiradical activity it can be concluded that the total content of phenolic compounds ($p = 0.001$) and anthocyans ($p = 0.000$) had a significant effect on it determined by DPPH reagent. However, by using ABTS reagent the effect of the content of total anthocyans ($p = 0.004$) is significant. After freezing the influence of vitamin C ($p = 0.04$) and total phenolic compounds ($p = 0.001$) on antiradical activity is significant by using DPPH reagent.

Antiradical activity in black currant berries has a little bit higher than in raspberries. It could be explained by the differences of biochemical composition, including diversity of anthocyans and higher content of vitamin C. The antiradical activity was highest in black currant 'Őjebyn' – by ABTS and DPPH reagent 53% (Figure 5.).

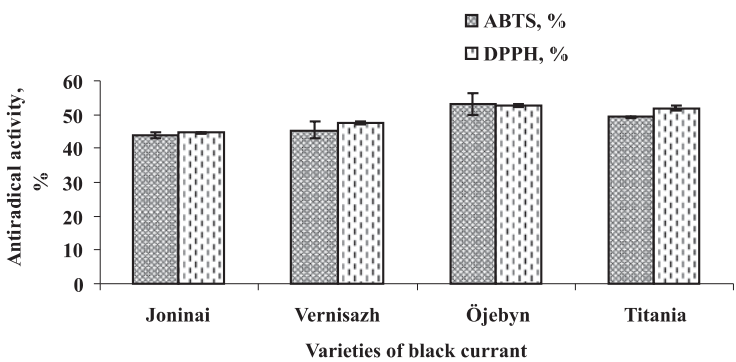

Figure 5. Radical scavenging activity of black currant fruits by different reagents

Conclusions

1. The average biochemical characteristic of sea buckthorn cultivars was – vitamin C - 84.9mg $100g^{-1}$, vitamin E – 23.2 mg $100g^{-1}$, total carotenoids – 14.5 mg $100g^{-1}$, total phenolic compounds – 126.1 mg $100g^{-1}$.
2. The results of the study show that the highest content of phenolic compounds among the analyzed black currant cultivars has 'Őjebyn' – 421.8 mg $100g^{-1}$ and among the raspberry cultivars – 'Norna' (372.6 mg $100g^{-1}$).
3. The highest content of anthocyanins has black currant cultivar 'Vernisazh' – 229.2 mg $100g^{-1}$, among raspberry cultivars 'Norna' – 33.9 mg $100g^{-1}$.
4. The highest content of ascorbic acid has black currant 'Joninainai' – 246 mg $100g^{-1}$, among raspberry cultivars 'Skromnitsa' – 38 mg $100g^{-1}$.
5. Black currant cultivar 'Őjebyn', raspberry cultivar 'Ottawa' and wild raspberries possess pronounced radical scavenging abilities.

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Table 1. Qualitative indices of frozen sea buckthorn fruits

Name of variety	Vitamin C, mg $100g^{-1}$	Vitamin E, mg $100g^{-1}$	Total content of carotenoids, mg $100g^{-1}$	Total content of phenols, mg $100g^{-1}$
'Prozrachnaya'	71.49	26.71	12.90	99.57
'Podarok Sadu'	99.25	31.92	20.65	129.40
'Botanicheskaya Lubitelskaya'	69.39	17.01	10.24	138.25
'Luchistaya'	66.60	16.41	8.43	121.24
'Avgustinka'	80.71	17.17	17.67	117.35
'Trofimovskaya'	88.55	28.60	16.11	132.48

THE CHANGES OF BIOCHEMICAL CONTENT IN SEABUCKTHORN (*HIPPOPHAE RHAMNOIDES* L.) DURING RIPENING

[1] Pranas VIŠKELIS, [1] Juozas LANAUSKAS, [2] Dalija SEGLIŅA, [2] Silvija RUISA

[1] Lithuanian Institute of Horticulture,
Kaunas Street 30, LT-5433 Babtai, Kaunas distr., Lithuania
e-mail: biochem@lsdi.lt
[2] Latvia State Institute of Fruit-Growing, Graudu 1, LV-3701 Dobele, Latvia
e-mail: dalija.seglina@lvai.lv

Abstract

Seabuckthorn fruits are a valuable raw material for the production of biologically active food products. Their content of vitamins, minerals and phenolic compounds depends on harvesting time. The cultivars studied in Lithuania were introduced from the Botanical Garden of Moscow State University. The plantation was established on sandy loam soil in 1998 in Kaunas district, Lithuania. The aim of the study was to determine the changes of physical and chemical parameters during the growing season (3rd decade of July – 3rd decade of September, 2006). It was found that the firmness of seabuckthorn fruits decreased from 43-63 N m^{-2} to 20-27 N m^{-2}. The highest content of sugars was found in the cultivar 'Trofimovskaya' at the end of the 3rd decade 5.8%), while the lowest content was in the cultivar 'Botanicheskaya' (4.1%). The content of total acids decreased from 2.7-2.9% to 1.1-1.4%. The highest content of vitamin C was found in the cultivar 'Trofimovskaya' whiles the lowest content was found in the cultivar 'Avgustinka'. The highest content of total carotenoids was found in the cultivar 'Trofimovskaya' (24.9%), and the lowest in the cultivar 'Botanicheskaya' (13 mg $100g^{-1}$). Therefore, we conclude that the optimal harvesting time of seabuckthorn fruits in Lithuania Kaunas district is in the 1st decade f September.

Key words: seabuckthorn, fruit firmness, sugars, total acids, ascorbic acids, harvesting time

Introduction

With the increasing demand for products containing natural biologically active substances, great attention has been paid to the seabuckthorn. The fruit of the seabuckthorn (*Hippophae rhamnoides* L.) not only has high nutritional value but also remedial value (Li and Beveridge, 2003; Li and Schroeder, 1996). They are valuable due to the high content of vitamins C, E, P, K, carotenoids and oil (Singh, 2005). Seabuckthorn leaves and skin also contain valuable substances. As a raw material, the seabuckthorn is essential in medicine, veterinary medicine and cosmetology (Bernath and Foldesi, 1992).

Populations of the seabuckthorn are very different in nature, but the individuals do not vary within the population (Tang and Tigerstedt, 2001). Different cultivars of seabuckthorn are adapted to different growing conditions, their fruits contain many biologically active substances, and it is easy to harvest them. In the period from 1984 to 1989, at the Lithuanian Institute of Fruit-Growing and Horticulture, 12 cultivars of the seabuckthorn created by the Altai Fruit-Growing Institute (Russia) were studied. Fruits of the given cultivars were larger (the mass of 100 fruits was up to 83 g) and easier to

pick. However, the greatest disadvantage of the Altai cultivars is high loss of seedlings. It is thought that the seedlings suffer from a drastic change of temperature during the winter period. The seabuckthorn cultivars are habituated to the continental climate and the climatic conditions of Lithuania were therefore unfavorable to them. In the conditions of our country, some cultivars created in the botanical garden of the Moscow State University grow better. These were grown in the collection of the Lithuanian Institute of Fruit-Growing and Horticulture in the period from 1986 to 1999, but they were not studied in detail.

Harvesting seabuckthorn is a very important issue. It has been proven that one worker can pick only 5-6 kg per day of small-fruit seabuckthorns (Михеев, Деменко, 1990). The amount of the yield increases if different auxiliary equipment is used, such as hooks, loops and special aprons onto which the fruits are shaken. However, even this method is not sufficiently effective (Varlamov et al., 1998; Mann et al., 2001). More promising are the mechanized ways of picking the fruits, where fruits of the seabuckthorn are shaken off or sucked off (Dolgosheev and Varlamov, 1998). The largest part of the seabuckthorn fruits sticks firmly to the branches, and the fruits are not always easily shaken down. When harvesting the fruits by suction, they can be mechanically damaged, and a wet mass is obtained. It is important to know whether the processors are ready to purchase the seabuckthorn fruits gathered in this way. In Russia and Mogilyev, research has been conducted to prove that gathering the seabuckthorn can be delayed until temperatures reach –16 °C (Dolgosheev and Varlamov, 1998). Frozen fruits can easily be shaken down. It is assumed that gathering the seabuckthorn would be quicker if branches with the fruits were cut and frozen and the fruits later shaken down.

The aim of this study is to evaluate the biological and economical properties of the seabuckthorn cultivars 'Avgustinka', 'Botanicheskaya', 'Podarok Sadu' and 'Trofimovskaya' (created in the botanical garden of the Moscow State University) and to evaluate opportunities to gather the seabuckthorn by cutting fruit-bearing branches.

Materials and methods

This research was carried out in 2006. The seabuckthorn plantation was arranged in the spring of 1998, when the annual plants were propagated by green cuttings. The pattern of the planting was 4x2 m. The arable layer of soil had pH 7.2, humus – 2.5%, content of P_2O_5 – 210 mg·kg^{-1}, K_2O – 180 mg·kg^{-1}. Four seabuckthorn cultivars were investigated: 'Avgustinka', 'Botanicheskaya', 'Podarok sadu' and 'Trofimovskaya'. While the fruit ripened, the yield of the seabuckthorn and changes in the mass were evaluated. The mechanical strength of the fruit skin and the power required to tear the fruit from the branch were determined.

During harvesting, manual gathering and branch cutting were compared. Before freezing, the annual shoots and the most of the leaves were cut off. Branches with fruit were frozen at -30 °C. The frozen fruits were shaken down from the branches. The yield of the seabuckthorn and the condition of the bushes were evaluated. The amount of seabuckthorn fruits gathered by cutting the branches was evaluated. Labor input necessary for manual gathering was evaluated. The data were statistically elaborated using dispersion analysis. The smallest essential difference limit ($p = 0.05$) was determined

for several parameters within the period from 20 August to 20 September, when the seabuckthorn fruits were manually gathered for the variety comparison testing.

The biochemical analyses of the fruits were carried out 5 times during the period from 25 July to 19 September.

Results

Changes in the average mass of the seabuckthorn fruits began to be evaluated with the first signs of ripening, that is, with changes in color. At the end of July and the beginning of August, the mass of 100 fruits was 38-44 g (Figure 1). On the 20th of August, when the fruits were picked for the yield evaluation, their mass reached 50-60 g. Until the end of the research, in the middle of August, the fruit mass of the cultivars 'Botanicheskaya' and 'Trofimovskaya' did not change. At the same time, the fruit mass of the cultivars 'Avgustinka' and 'Podarok Sadu' increased to 70g. With the fruit ripening, the mechanical strength of the fruit skin decreased from 43-63 N m^{-2} at the end of July to 20-27 N m^{-2} in the middle of August (Figure 2). During the gathering in bulk, the mechanical strength of the fruit skin was lower for the fruits of the cultivar 'Botanicheskaya' (23 N m^{-2}), but larger for the cultivars 'Trofimovskaya' and 'Avgustinka' (44 and 39 N m^{-2}, respectively). The higher mechanical strength of the fruit skin for the last two cultivars remained constant until the end of the research period.

During the ripening period, the force required to tear the seabuckthorn fruits from the branches increased slightly, from 1.8-2.1 N on 08 August to 2.1-2.3 N on 19 September (Figure 3). During the fruit gathering in bulk, the fruits of the cultivar 'Avgustinka' held the strongest to the branches, where a 2.3 N force was needed to tear them off.

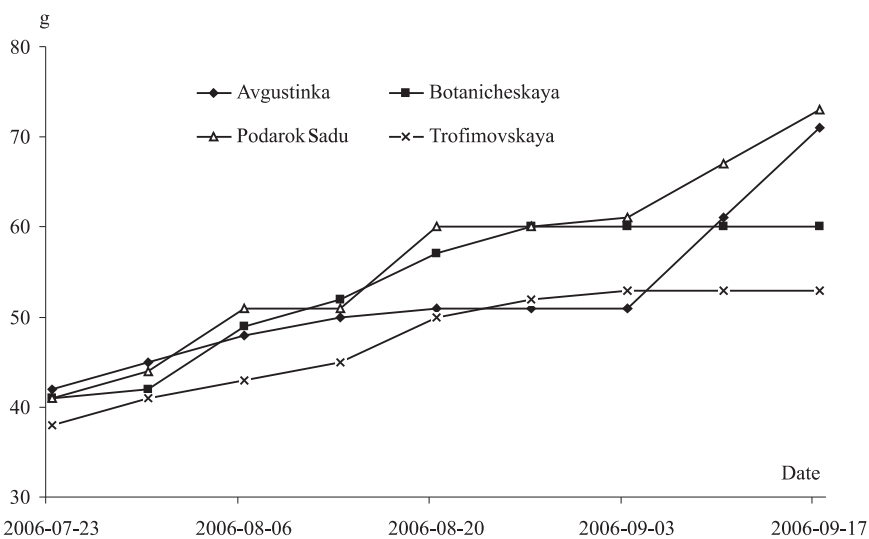

Figure 1. Changes in the mass of 100 seabuckthorn fruits during fruit ripening.
LSD_{05} = 6.8 (06.08.20); LSD_{05} = 11.7 (06.09.17.)

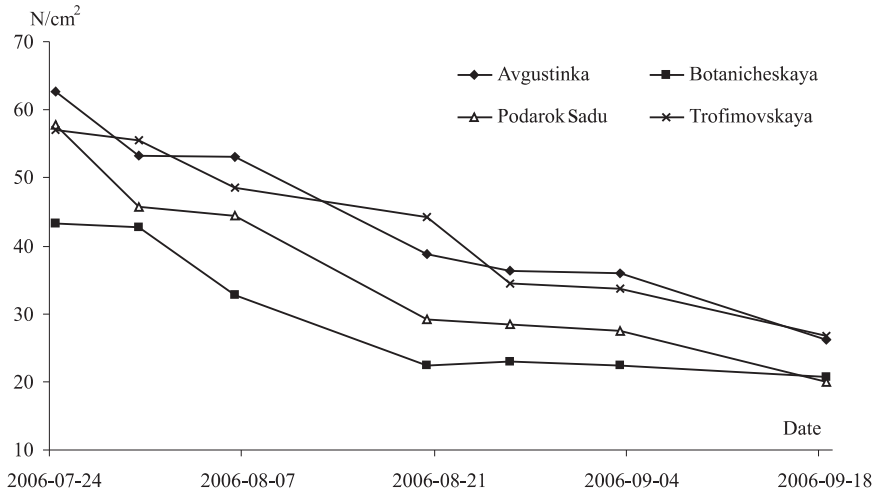

Figure 2. Changes in the mechanical strength of the fruit skin during fruit ripening. LSD_{05} = 6.9 (06.08.20)

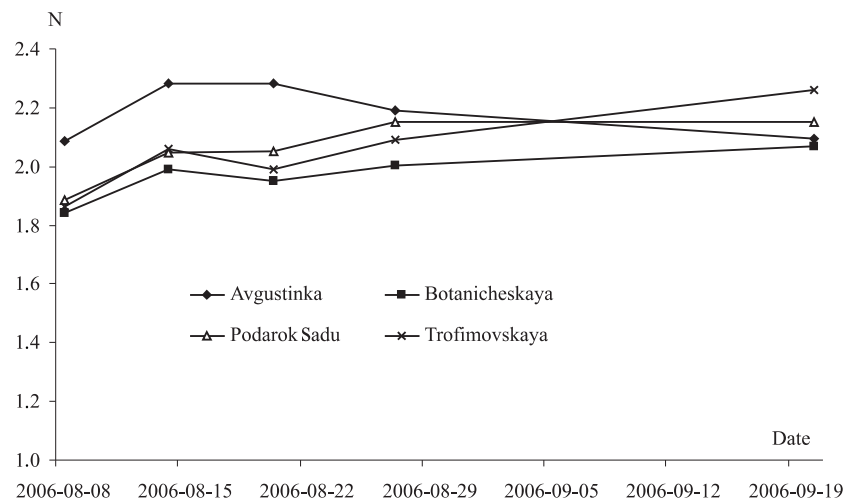

Figure 3. Changes in the force required to tear sea buckthorn fruits from the branch during fruit ripening. LSD_{05}=0.22 (06.08.22).

Having evaluated the productivity of the seabuckthorn, we conclude that the most productive was the cultivar 'Avgustinka', its yield reached 11.3 t ha^{-1} (Table 1). Less productive was the cultivar 'Botanicheskaya' at 8.0 t ha^{-1}. When cutting with knives, the most productive was the cultivar 'Podarok Sadu' at 13.1 t ha^{-1}. Compared to the manual gathering of the seabuckthorn fruits, the yield result was slightly lower when cutting the branches. This can be explained by the fact that the branch-cleared fruits are not

mechanically damaged, but manually gathered fruits often are broken and the juice that flows out causes losses to the mass. The yield of the seabuckthorn fruits when cutting the branches was 77-82%.

The total sugar content of fruits at ripening essentially did not change (Figure 4). During gathering, the highest sugar content was found in the fruits of the cultivar 'Trofimovskaya' (19.7%).

The content of the soluble solids did not alter during the ripening period. Slight changes were observed in the fruits of the cultivar 'Podarok Sadu'– from 9.95% to 11.10% (Figure 5). The highest content of soluble solids was found in the fruits of the cultivar 'Trofimovskaya', while the lowest was found in the fruits of 'Botanicheskaya'.

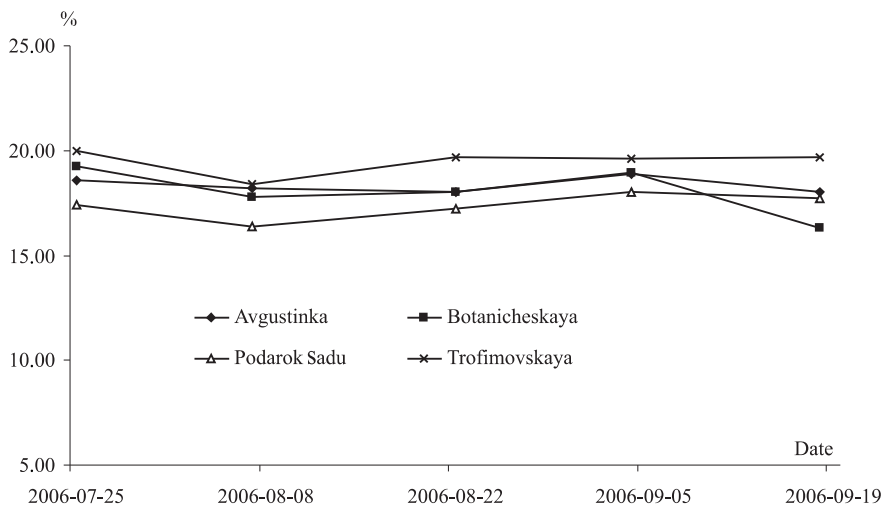

Figure 4. Content of dry matter in seabuckthorn fruits during fruit ripening. LSD_{05}=1.51 (06.08.22).

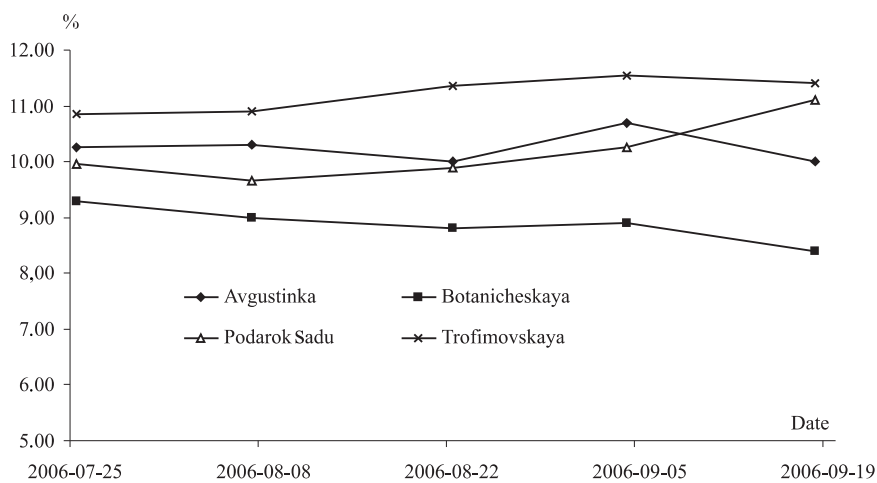

Figure 5. Content of soluble solids in seabuckthorn fruits during fruit ripening. LSD_{05}=1.06 (06.08.22).

The total sugar content during the ripening of the seabuckthorn fruits increases, reaching its maximum, then decreases. The highest sugar content was observed in the fruits of the cultivar 'Trofimovskaya' on the 22nd of August (5.8%), while the lowest was observed in the fruits of the cultivar 'Botanicheskaya' (4.1%) (Figure 6).

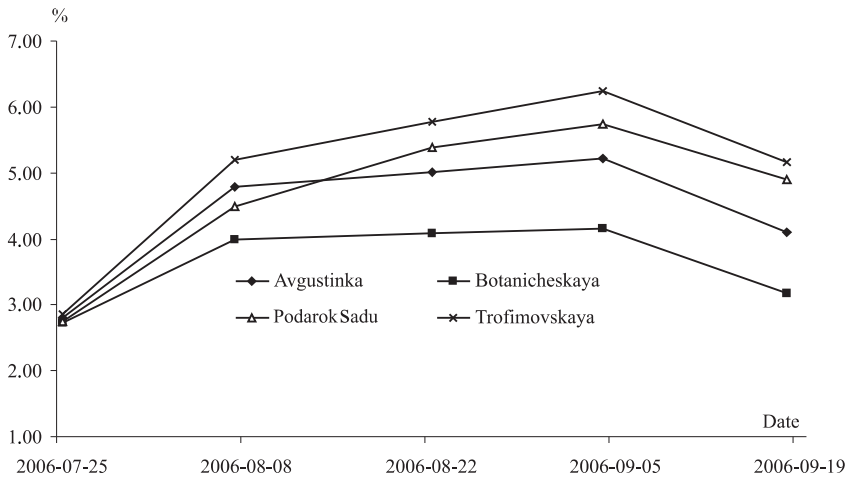

Figure 6. Total sugar content of seabuckthorn fruits during fruit ripening. LSD_{05}=0.77 (06.08.22).

During the period of ripening, the total acid content of the seabuckthorn fruits decreased from 2.7-2.9% to 1.1-1.4%. However, essential differences between the cultivars were not observed (Figure 7). The lowest total acid content was observed in the fruits of the cultivar 'Botanicheskaya'.

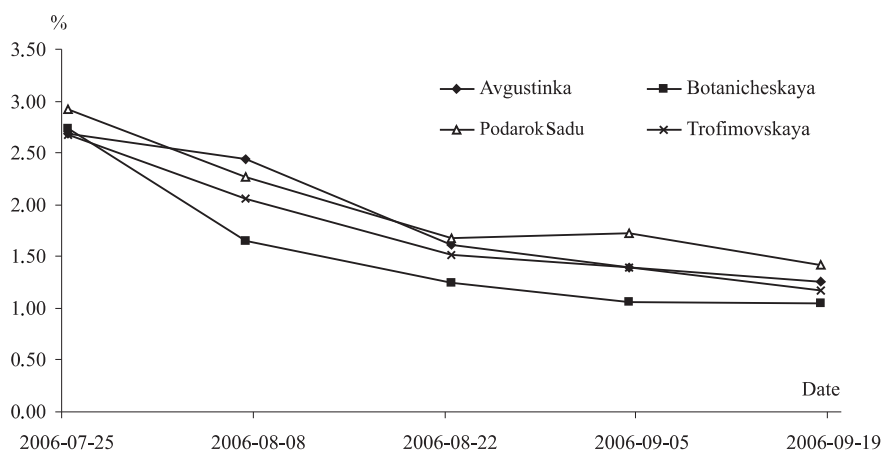

Figure 7. Total acid content in seabuckthorn fruits during fruit maturity, LSD_{05}=0.33 (06.08.22).

The content of vitamin C decreases during the ripening of the seabuckthorn fruits (Figure 8). Essential changes were observed at the end of July and the beginning of August. The highest vitamin C content was observed in the fruits of the cultivar 'Trofimovskaya', while the lowest was found in the fruits of the cultivar 'Avgustinka'.

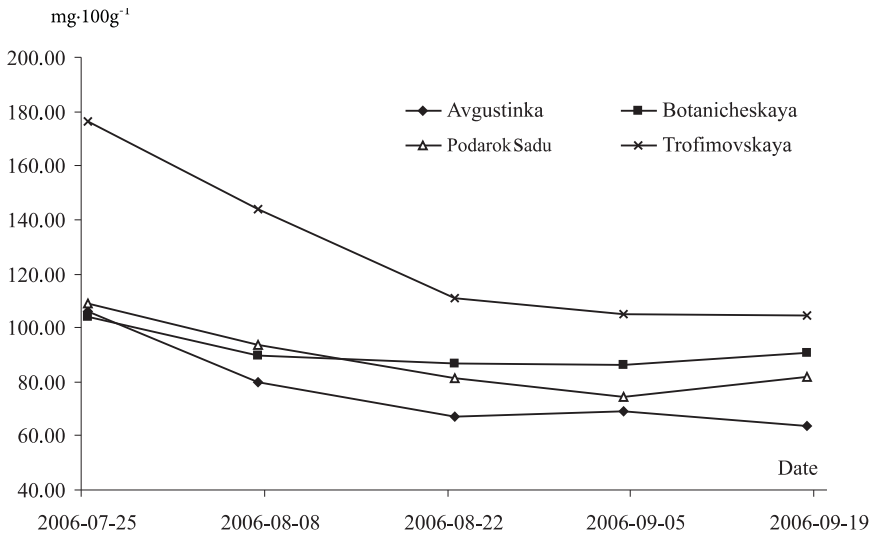

Figure 8. Ascorbic acid content in seabuckthorn fruits during fruit ripening. LSD_{05}= 9.44 (06.08.22).

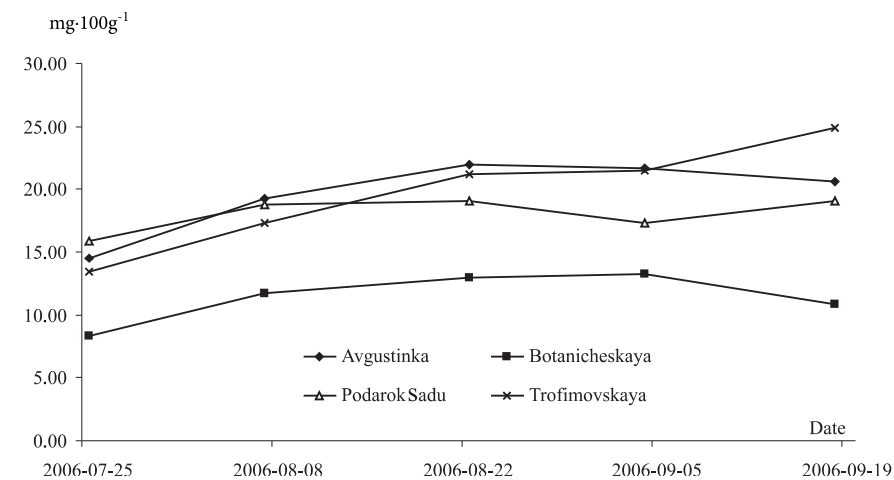

Figure 9. Content of carotenoids in seabuckthorn fruits during fruit ripening. LSD_{05}=4.54 (06.08.22).

The total content of carotenoids in the fruits of the cultivars 'Botanicheskaya' and 'Avgustinka' increased, reaching its maximum during ripening, and did not change afterwards. However, with the cultivars 'Trofimovskaya' and 'Podarok Sadu', the total content of carotenoids increased until the end of the research period (Figure 9). The

highest content of carotenoids was found in the fruits of the cultivar 'Avgustinka' (21.9 $mg \cdot 100g^{-1}$) on the 22nd of August, and the lowest was found in the cultivar 'Botanicheskaya' (13 $mg \cdot 100g^{-1}$). At the end of the research period, the highest content of carotenoids was observed in the fruits of the cultivar 'Trofimovskaya' (24.9 $mg \cdot 100g^{-1}$).

Discussion

The data obtained in this study show that, during ripening, the fruit gathering process becomes more complicated – the density of the fruit skin becomes lower, but the tearing force of the fruits from the branches essentially does not change. A close negative correlation exists between the density of the fruit skin and the average fruit mass: for the cultivar 'Botanicheskaya', r = -0.99, while for the other varieties this value is r = -0.84. Despite the increase in mass during ripening, it is not advisable to delay fruit gathering. The gathering time could be extended by cutting fruit-bearing branches, freezing them and later shaking them down. Using such a method, the decrease in the mechanical strength of the fruit skin does not affect the fruit quality. It is advisable to further study the gathering methods for the seabuckthorn fruits using branch cutting in Lithuania and Latvia. Presently, it is not clear how branch cutting affects the regeneration of the seabuckthorn bushes or how much time will pass until the next full yield. The research carried out in Estonia shows that, in the third year after cutting, the seabuckthorn bushes start to lose yield, but after one more year, the yield was rich (r = -0.84) (Jalakas et al., 2003).

The extension of the gathering time is an essential factor also from another point of view – with the increase of the fruit mass, essential negative biochemical changes are not observed. The content of some components (sugar, carotenoids) increased, but the total acid content decreased, which makes the fruits of the seabuckthorn a valuable raw material for the production of food products.

Conclusions

Summing up the results obtained in 2006, it is possible to conclude that the highest yield was obtained from the cultivars 'Avgustinka' and 'Podarok Sadu' by manually gathering, where the yields averaged 11.3 and 10.9 t ha^{-1}, respectively. However, cutting the branches yielded 11.4 and 13.1 t ha^{-1}, respectively. When cutting the branches, the yield of fruit reaches 80%.

The highest content of total and soluble solids, total sugars and vitamin C is in the fruits of the cultivar 'Trofimovskaya'. The highest content of carotenoids is in the fruits of 'Avgustinka' and 'Trofimovskaya'.

During ripening, the mass of thesea buckthorn fruit increased, the mechanical strength of the fruit skin decreased, and the tearing force from the branches did not change. The total sugar content first increased then reached its maximum and decreased; the total acid and vitamin C content decreased, but the content of carotenoids increased. During fruit ripening, the total sugar content and soluble solids content did not change.

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Table 1. Seabuckthorn yield, Babtai, 2006

Cultivar	Yield, t ha^{-1}		Yield, %
	Manually gathered	Cutting branches	
'Avgustinka'	11.3	11.4	82 c*
'Botanicheskaya'	8.0	10.1	79 abc
'Podarok Sadu'	10.9	13.1	77 a
'Trofimovskaya'	9.2	7.7	81 bc
LSD_{05}	2.40	3.91	
Average	9.8	10.6	
LSD_{05}	0.77		


Restorāns Formula