Eesti Maaülikool
Estonian University of Life Sciences

PEREKONNA MURAKAS (*RUBUS*) MÕNEDE LIIKIDE SAAGIKUS JA VILJADE KVALITEET

YIELD AND FRUIT QUALITY OF SOME SELECTED BRAMBLE (*RUBUS*) SPECIES

ELE VOOL

Väitekiri
Filosoofiadoktori kraadi taotlemiseks taimekasvatuse erialal

A Thesis
for applying for the degree of Doctor of Philosophy in Plant Production

Tartu 2009

ELE VOOL PEREKONNA MURAKAS (*RUBUS*) MÕNEDE LIIKIDE SAAGIKUS JA VILJADE KVALITEET

VIIS VIIMAST KAITSMIST

MATI ROASTO
CAMPYLOBACTER SPP. IN POULTRY AND RAW POULTRY MEAT PRODUCTS IN ESTONIA WITH SPECIAL REFERENCE TO SUBTYPING AND ANTIMICROBIAL SUSCEPTIBILITY.
KAMPÜLOBAKTERITE ESINEMINE EESTIS KODULINDUDEL JA TOORETES LINNULIHATOODETES, TÜVEDE TÜPISEERIMINE JA ANTIBIOOTIKUMIDELE TUNDLIKKUSE MÄÄRAMINE
Prof. Marja- Liisa Hänninen
Visiting Prof. Ari Hörman
Associate Prof. Priit Elias
April 25, 2008, at 10.00

RUTH LAUK
KAUN- JA TERAVILJADE SEGUKÜLVIDE KASVATAMISE TEOREETILISI JA PRAKTILISI ASPEKTE
THEORETICAL AND PRACTICAL ASPECTS OF GROWING LEGUME-CEREAL MIXES
Prof. Ervi Lauk, DrSci
May 29, 2008, at 10.00

ANU KISAND
SEDIMENT PHOSPHORUS FORMS AND THEIR ROLE IN LAKE ECOSYSTEMS
SETTEFOSFORI VORMID NING NENDE MÕJU JÄRVEDE ÖKOSÜSTEEMIDELE
Tiina Nõges, PhD
June 6, 2008, at 11.00

MAREK METSLAID
GROWTH OF ADVANCE REGENERATION OF NORWAY SPRUCE AFTER CLEARCUT
HARILIKU KUUSE EELUUENDUSE KASV LAGERAIE JÄRGSELT
Kalev Jõgiste, PhD
Prof. Eero Nikinmaa
August 29, 2008, at 10.00

IVI JÕUDU
EFFECT OF MILK PROTEIN COMPOSITION AND GENETIC POLYMORPHISM ON MILK RENNET COAGULATION PROPERTIES
PIIMA VALGULISE KOOSTISE JA GENEETILISE POLÜMORFOSMI MÕJU PIIMA LAAPUMISOMADUSTELE
Prof. Olav Kärt,
Prof. emer. Olev Saveli
Scientific consultant Merike Henno, PhD
August 29, 2008, at 12.00

ISBN 978-9949-426-60-7

roheline trükis
Trükitud taastoodetud paberile looduslike trükivärvidega. ©Ecoprint

EESTI MAAÜLIKOOL
ESTONIAN UNIVERSITY OF LIFE SCIENCES

Eesti Maaülikool
Estonian University of Life Sciences

PEREKONNA MURAKAS (*RUBUS*) MÕNEDE LIIKIDE SAAGIKUS JA VILJADE KVALITEET

YIELD AND FRUIT QUALITY OF SOME SELECTED BRAMBLE (*RUBUS*) SPECIES

ELE VOOL

Väitekiri
Filosoofiadoktori kraadi taotlemiseks taimekasvatuse erialal

A Thesis
for applying for the degree of Doctor of Philosophy in Plant Production

Tartu 2009

Department of Horticulture
Institute of Agricultural and Environmental Sciences
Estonian University of Life Sciences

According to verdict No 45 of February 18, 2009 the Doctoral Committee of the Institute of Agricultural and Natural Sciences of the Estonian University of Life Sciences has accepted the thesis for the defence of the degree of Doctor of Philosophy in Plant Production.

Opponent: Associate
Prof. Torben Bo Toldam-Andersen PhD
University of Copenhagen
Department of Agriculture and
Ecology/Crop Science

Supervisor: **Prof. Kadri Karp, Dr. Sci.**,
Estonian University of Life Sciences

Defence of the thesis: Estonian University of Life Sciences, room 2A1
Kreutzwaldi 5, Tartu, on March 30, 2009, at 10.00

The publication of this thesis was funded by Estonian University of Life Sciences

ISBN 978-9949-426-60-7

CONTENTS

LIST OF ORIGINAL PUBLICATIONS

This thesis is a summary of the following papers, which are referred to by Roman numerals in the text. All papers are reproduced with due permission from the publishers.

I. Noormets, M., **Vool, E**., Karp, K., Värnik, R., Starast, M. 2003. New trends in development of Estonian berry production towards to sustainable agriculture. Integrative approaches towards sustainability in the Baltic Sea Region, 15: 467-473.

II. **Vool, E.,** Noormets, M., Karp, K., Mänd, R., Starast, M. 2003. Pollinators and their foraging behaviour in arctic bramble (*Rubus articus* L.) plantations in Estonia. Integrative approaches towards sustainability in the Baltic Sea Region, 15: 481-489.

III. **Vool, E**., Karp, K., Moor, U., Starast, M. 2007. Yield quality in some taxa of the genus *Rubus* depending on the cultivation technology. European Journal of Horticultural Science, 72 (1): 32-38.

IV. **Vool**, **E**., Noormets, M., Karp, K., Moor, U., Starast, M. The Productivity and Fruit Quality of the Arctic Bramble (*Rubus arcticus* ssp. *arcticus*) and Hybrid Arctic Bramble (*Rubus arcticus* ssp. *arcticus* x *Rubus arcticus* ssp. *stellatus*). Acta Agriculturae Scandinavica, Section B- Soil and Plant Science (in press).

LIST OF ABBREVITATOINS AND SYMBOLS

+a* - fruit redness
AA - ascorbic acid
AAC - ascorbic acid content
DM – dry matter
L* - lightness
LSD - least significant difference (statistic)
SS - soluble solids
SSC - soluble solids content
SS:TA - soluble solids and titratable acids ratio
TA - titratable acids

INTRODUCTION

The situation in berry growing has considerably changed in Estonia compared to the one at the beginning of the 1990s. The ownership reform, where the unlawfully expropriated land was returned to its legal successors, caused an increase of the number of the small farms. The above mentioned small farms became interested in development and prevalence of berry cultivation. The general plantation area of berry growing farms kept constantly growing until 2001 (Statistical Office of Estonia, 2002), though started to decrease after that year. As a result of a questionnaire organized by the economists of Estonian University of Life Sciences (EMÜ), it became apparent that the major causes for that decrease were; scanty experience of the berry growers, small profitability of production, small cultivation areas, lack of finance for investing, lack of workforce during the harvesting period, growth of competition, etc. (EMÜ, 2007).

In Nordic countries, berry growing has always been risky and the risk is mainly caused by climatic conditions that influence the yield and its quality. However, there is a possibility to decrease those risks by selecting the cultures, which are, primarily, less affected by the ambient factors. It is important to continue enriching the list of berry cultures, selecting the species and cultivars that are tolerant to harsh Northern weather. The number of berry cultivating farmers or production areas growth could certainly be increased if winter-tolerant and disease-resistant cultures were more accessible and berry growers had more knowledge. It would be a great help if it were possible to decrease expenditure on cultivating plantations.

The genus *Rubus* is wide spread both in natural conditions and plantations and is well known for its species. The biggest plantations are those of red raspberry (*Rubus idaeus* L.) and blackberry (*R. plicatus* Weihe & Nees = *R. fruticosus* L.). Raspberry has a longer cultivation history in Nordic countries, including Estonia, due, unquestionably, to the fact that raspberry is the most aggressive invading plant in Northern hardwood forests (Whitney, 1982). According to the year 2005 statistical data, raspberry was grown on 100 939 ha worldwide, where European area accounts for 88 165 ha (FAOSTAT, 2008). Since 1980, the country that has most intensively been breeding raspberry cultivars has been the USA, followed closely by Canada, England and Scotland (Finn, Knight, 2002).

Raspberry cultivars reached Estonia for the first time at the beginning of the 19th century. However, research work with cultivars started in 1927 at the Experimental Horticultural Station of the University of Tartu, where 16 cultivars were under observation at the time (Parksepp, 1977). Despite the growing popularity of such new berry crops (grown to a smaller extent so far) as sea buckthorn (*Hippophäe rhamnoides* L.), blueberry (*Vaccinium* L. sp.) and grape (*Vitis* L. sp.) in Estonia, there is a continuous demand among berry producers and grower for raspberry. This is also proved by the fact that at the beginning of 2008 Polli Horticultural Research Centre issued certificates for three new raspberry cultivars (Polli Horticultural Research Centre, 2008). The fact that cultivars breed in Estonia have high-yield and are winter-tolerant, is also supported by the research conducted at the Estonian University of Life Sciences in 2007. According to this research, raspberry cultivar Tomo formed 34% of the total area of Estonian planted area. In 2006, in Estonia, there were 3830 ha of berry plantations (Estonian Horticultural Association, 2008).

Blackberry cultivation in 2005 was an estimated 20 035 ha planted and commercially cultivated worldwide (Strik *et al.*, 2008). There were 7692 ha of commercially cultivated blackberries in Europe with Serbia accounting for 69% of the area in Europe. The next largest producing countries in Europe were Hungary, the UK and Romanian. In Estonia, blackberry is being grown only on a couple of hectares. Blackberry has not gained popularity in North-Europe because of its poor winter-hardiness and difficulties in fruit handling due to thorns on the stems (Finn, Knight, 2002). Plant breeding of bramble is most intensive in America and in New Zealand. At least 59 cultivars have been released from 1985-2005 worldwide (Clark, Finn, 2008). In Estonia, experiments with blackberry were carried out in 1954–1959, when yield data and biochemical components of fruits were observed (Parksepp, 1977).

Because of a limited geographic area of distribution, arctic bramble (*R. arcticus* L. ssp. *arcticus*) plantations are by far not particularly numerous. Arctic bramble needs a cool summer and a long day for good growth and that is why it can be grown only in Northern countries (Karp, Starast, 1999). The arctic bramble growing areas are located in a broader zone in Asia, from 50° to 70° latitude, as well as in northern parts of North America, i.e. Canada and Alaska. The best Eurasian habitats are located between 62° and 66° latitude. Estonia is situated on the southern boundary of the arctic bramble's area of distribution.

The arctic bramble cultivars are mostly bred in Finland and Sweden. In Finland, the breeders are focused on selecting the best clones of arctic bramble; in Sweden, plant breeding of hybrids is also in the focus of interest (Ryynänen, 1972; Larsson, 1980). In 1999, in Finland the arctic bramble plantations areas covered 20–25 ha, in Sweden - 10–15 ha (Anon, 1999). A decrease of arctic bramble natural growth areas in the 1970s and 1980s in Finland increased the necessity of growing arctic bramble at plantations (Kokko *et al*., 1993). The first arctic bramble experiments were carried out in Finland in early 1970s (Ryynänen, 1973). Collaboration with food industry research was initiated in order to make the process more efficient. The arctic bramble is under protection in Estonia since 1958 (Estonian Red Data Book, 1998). Its area of distribution has been diminishing constantly due to the amelioration activities. The Department of Horticulture of the Estonian University of Life Sciences started experiments on arctic bramble cultivation in 1995. The first studies have demonstrated that cultivation of the arctic bramble in Estonia is quite promising (Karp, Starast, 1997).

1. REVIEW OF THE LITERATURE

1.1. CULTIVATION OF RASPBERRY AND BLACKBERRY

Raspberry is a diploid species of the *Idaeobatus* subgenus, blackberry - a polyploid species of the *Rubus* L. subgenus, the number of chromosomes of which remains between 2n and 12n. In 1753, Carl Linné gave a general name *Rubus fruticosus* to all cultivated blackberries. The major species of bramble, cultivated in Europe, are tetraploid (Inosemzev, 1992). As a result of interbreeding between species and within species, hybrids have been cultivated, which are notably different by their properties from the base species. Regardless of the fact that these berries are bigger and, thus, more transport-proof (Jennings, 1988), the hybrids of the species mentioned are less popular among farmers. As some of them have definite cultivar characteristics, they are treated as a separate species of the genus *Rubus*. The most successful and important hybrid is, by common opinion, the hexaploid 'Loganberry' (*R. loganobaccus* L.H. Bailey), discovered in 1883 in California (Jennings, 1988). The 'Tayberry' cultivated in Estonia has an octaploid chromosome system. An advantage of this hybrid is the location of its fruits on short side branches, which simplifies harvesting, and its apparent resistance to fruit infections (Jennings, 1988; Luffman, Buszard, 1989).

Blackberries have several positive characteristics, such as deep extending root system, which enables better survival in drought periods; ripe fruits better steadiness on stems; good pest resistance and transportation strength (Finn, Knight, 2002). Moreover, blackberry has a late blooming time and, therefore, generative organs damage, caused by spring frosts, is limited. This fact makes this berry suitable for cultivation in regions, where late spring frosts occur. Slight winter hardiness and late ripening are the main reasons why blackberry with its rich choice of cultivars is not very widely spread in Northern countries (Selonen, Tigerstedt, 1989). In case of blackberry, the vegetation period remains too short and that is why the fruit fails to ripen completely before autumn frosts. In introducing cultivars, knowledge of the fact that erect blackberries can survive much lower winter temperatures (less than –15°C) than trailing types, and thorny cultivars are more winter hardy than thornless types would be fairly helpful (Warmund, George, 1990). However, 25% of blackberry cultivars planted worldwide is erect types (Strik *et al*., 2008). It was also found, that the longest canes or branches of *Rubus* taxa were more susceptible to winter injury (Gundersheim, Pritts, 1989).

In the case of raspberries, cultivars successfully grown in neighboring countries should be preferred. Cultivars Alvi and Aita, breed in 2003, are promising regarding the size of their fruits (Arus *et al.,* 2008). Unfortunately, winter hardiness of the latter is not as good as that of the former. In addition to the damages caused by genetic properties, damages of raspberry canes are also caused by the rise of temperature over –6.6ºC during the dormant phase (Shoemaker, 1958). For several years, a more winter hardy and yielding cultivar has been 'Tomo' breed from cultivars of Russia ('Novost Kuzmina') and British ('Superlative') origins (Libek *et al*., 2003). One of the stating points for 'Alvi' and 'Aita' has also been 'Novost Kuzmina'. Thus, more winter hardy cultivars are found for the Estonian climate, using cultivars of Russia origin for crossing.

One of the most laborious tasks in berry cultivation is weed control. Mechanical and chemical weed control methods are effective and possible before starting a plantation. However, they turn to be inefficient at already cultivated plantations due to various reasons that are to be considered below. The more widely spread means of weed control upon environmentally sustainable growing are mulches. Mulch application as weed controller can minimize problems associated with herbicides and it is a practice often used by organic growers to suppress weeds (Jensen, Yarborough, 2004; Jordan, 2004). Percival *et al*. (1998) described the positive influence of mulching on raspberry and blackberry root system development. Since blackberries have a deep root system, compared to the raspberry, the positive influence of mulching may be limited to only suppressing weeds in first growing years. Beneficial effects of plastic film on raspberry vegetative growth and yield components have been noticed as well (Percival *et al*., 1998; Heiberg, 1999; Libek, Kikas, 2000; Nes *et al*., 2008). Therefore, thicker canes allowed a greater percentage fruit set and produced more berries per cane and per lateral (Crandall *et al.,* 1974a and b). Nes *et al*. (2008) find cane density significant effect on yield. Pedreros *et al.* (2008) do not recommend to use wheat straw mulch, as this may prevent plant growth. In an experiment, where organic and polyethylene mulches were compared, it was found that plants may catch raspberry anthracnose more often at plantations where plastic mulches were used compared to those using peat mulches (Hanni, Libek, 2003)

1.2. CULTIVATION OF ARCTIC BRAMBLE

In the genus of bramble hybrids between different species are easily breed. A hybrid of the arctic bramble and *R. saxatilis* L. has been found in nature in Estonia. This hybrid is also known as *R. castoreus* Laest. In Estonia, such hybrid was found first in 1935 in Kaansoo bog (Reier, 1982). In Finland and Sweden, hybrids of arctic bramble and raspberry are found growing naturally (Larsson, 1969). When joining the properties of raspberry and arctic bramble in Finland and Sweden, the first cultivar was got called 'Merva' (Hiirsalmi, 1975). The first Swedish hybrid cultivars (*R. arcticus* ssp. *arcticus* x *R. arcticus* ssp. *stellatus*) were released in 1980 (Larsson, 1980).

Cultivation of arctic bramble is fairly riskier. The main problem of arctic bramble cultivation is a downy mildew (*Peronospora sparsa* Berk.) infection (Kokko *et al*., 1999). As much as 50% of the whole yield can be destroyed by the disease (Karp, 2001). Blocking the spreading of the disease is difficult because the pathogenic germs hibernate in the underground parts of the plants and this makes leaves' mechanical picking ineffective (Lindgvist *et al*., 1998). Chemical control, however, is not advisable because of the deposition of the residue of the fungicides in fruits as to control the disease sprinkling must take place during the period of fruit ripening. The infection is mainly caused by unstable temperature in spring and stress in plant caused by water deficiency. At underwood growth sites the temperature is somewhat more stable but also colder than on an open ground. In the shade of the wood, the bramble suffers less from the frosts (Ryynänen, 1973). On an open ground, frosts during the blooming period are problem for they can destroy the blossoms. According to data from Finland, the bramble blossoms can withstand a frost of -2.6°C and will produce normal fruit (Ryynänen, 1973). Half open blossoms are most susceptible to frosts. Any temperature below -4°C destroys all blossoms. Long-term low temperature of some degrees over zero (2°...5°C) will prevent the development of pollen, so that the stigma will be destroyed and the blossoms wither.

Depending on prevailing environmental conditions, the second, most important problem is young shoots rapid growth in early spring. The young shoots can, therefore, be damaged by late spring night frost (Tammisalo, 1988; Karp *et al*., 2000b). Using straw cover will put off the beginning of plant growth and due to that the danger of frost damage of young shoots will decrease (Karp *et al*., 2000b).

The third problem in Estonia is too high temperature at plantations in summer. Therefore, partial shading is recommended to suppress rapid growth of arctic bramble in early spring and to reduce temperature in summer. Arctic bramble can be cultivated alternately with other species, for example raspberries. In the experiments in Northern Finland, the spruce (*Picea abies*) hedge was used to give shade (Prokkola *et al*., 2001).

The arctic bramble is an insect-pollinated plant; therefore, its productivity greatly depends on pollinators. Their pollinating efficiency is limited by the thermal constrains on flight activity, and each species has a micro-climatic 'window' within which foraging flight can be sustained (Corbet *et al*., 1993). On the other hand, the qualitative pattern of bramble pollinators in a plantation depends on plant communities around it and on both the number of pollinator species inhabiting these communities and the number of individuals within each species (Krearns *et al*., 1998). However, there is little published information on the foraging behaviour of pollinators on the arctic bramble, although some data from Finland have been reported (Ryynänen, 1973; Kangasjärvi, Oksanen, 1989). In Central Finland, the most frequent visitors of arctic bramble flowers included bumblebees (*Bombus* sp. Latreille) and honey bees (*Apis mellifera* L.) from among *Hymenoptera* L. and hover flies (family *Syrphidae*) and some other from among order *Diptera* L. (Ryynänen, 1973).

Because of the self-sterility of the arctic bramble, it is advisable to grow several cultivars alternating in a row. As the arctic bramble produces underground stolons which grow at least 0.5 m a year (Ryynänen, 1973), then in the experiment planting in rows (33 cm between the plants) it could be seen that by the third year after planting the shoots of one cultivar have grown out of the mulch hole of the other cultivar. In establishing the experiment, the cultivars were separated with borders to avoid mixing of the rhizomes of different cultivars (Starast *et al*., 2000; Karp, 2001). However, in order to guarantee better conditions for cross-pollination, it is better to use plastic mulches, which prevents dominating of the clone with better growth ability in the row (Mänd *et al*., 2001). Plastic helps to retain humidity, to control the growth of weeds and keeps the fruits clean (Kokko *et al*., 1993). However, a shortcoming of plastic is that it causes very early blooming of brambles during the period of night frosts, when the number of pollinators is small (Starast, 1998).

An important influence in respect of the yield characteristics is genotype. So, it has been found that Swedish hybrid cultivars, compared to the arctic bramble cultivars, are thought to be more opulent and productive, but have a weaker aroma (Larsson, 1980). However they are more resistant to downy mildew fungus (Hellqvist, 2000).

Vegetative growth characteristics such as the size of leaves and the length of shoots are important and affect the picking of the yield. Such cultivars as Aura and Astra have been of higher height (Karp, 2001), which shows that hybrids have better cultivar properties for production plantations than cultivars of arctic bramble. Studies of Estonian arctic bramble cultivars have demonstrated that the Estonian clone had good vegetative growth and yield – in the first year of the yield, it even exceeded the yield of all Finnish cultivars (Karp, Starast, 1999). Finnish cultivar Mespi and hybrid cultivars Aura and Astra demonstrated as well a good yield in earlier Estonian experiments (Karp, Starast 1998a; Karp, Starast 1998b; Karp, 2001). 'Astra' produced berries with a better colour which means, that their juice is darker (Starast *et al*., 2000). According to the data in literature, Swedish hybrid cultivars have high yield and are resistant to diseases (Larsson, 1980).

1.3. FRUIT QUALITY IN THE GENUS RUBUS

The value of the berries lies in their rich biochemical composition and the popularity of their consumption, and in people's awareness of these facts. Blackberry is at the top of more than 1000 antioxidant foods consumed in the USA (Halvorsen *et al*, 2006). Studies have shown that the ranking of antioxydant compounds from higher to lower content in the genus *Rubus* is: black raspberry, blackberry, red raspberry (Moyer *et al.,* 2002). The berries of the *Rubus* taxa are an important raw material in food production, especially, due to their pleasant aromatic taste.

The majority of berry deteriorate quickly. That is why it is important to find a way to preserve them so that all their useful bioactive substances would persist. For the fresh market, red raspberries are best when bright red and can be stored at 0°C only for several days. The simplest way to store berries is freezing them, but that results in organic acids and ascorbic acid content decrease by 19% and 22%, respectively, if compared to fresh berries (Kelt *et al.,* 1997). Melted berries taste sourer than the fresh berries. At the same time a nice smell, colour, and taste are preserved.

The growth area notably influences the content of sugars; thus, raspberries growing in more southern countries contain twice as much sugar compared to those growing in more northern areas (Green, 1971). Accumulation of reducible sugars like fructose and glucose in fruits takes place until fruit ripening and decreases after that. In raspberries, intensive saccharose (nonreducing sugar) also called sucrose accumulation takes place 4-5 days before ripening. Saccharose content is 4 times less than the content of reducible sugars. The proportions of fructose, glucose and sucrose are important when assessing fruit quality, as fructose is 1.8 times sweeter than sucrose (Green, 1971; Doty, 1976). The fruit yielded at 50% or more advanced maturity had the capacity of attaining comparable levels of soluble solids and titratable acid as those yielded at 100% maturity (Wang *et al*., 2009). In Estonia, the total content of sugars varies by cultivars, between 3.4–8.6% (Parksepp, 1977). Raspberry cultivars breed in Estonia contain 5% of sugars on average. Sugar content is higher in 'Tomo' and 'Helkal' but 'Tomo' has at the same time the highest acidity (Kelt *et al*., 1997; Kikas *et al*., 2002; Libek *et al.,* 2003*;* Arus *et al*., 2008). The average sugar content of blackberries (8.6%) is remarkably higher in Estonia if compared to raspberries (Kelt *et al*., 1997). Upon the data of Green (1971) the average sugar content of blackberries is 4.3%, that of 'Boysenberry' 'Loganberry' hybrids - 3.3% and 3.4% respectively. The sugar content of the arctic bramble in Finland is 3.8–6.1% (Häkkinen *et al*., 1994). Arctic bramble fruits are mainly used as raw material in food and liqueur industry. In the same way, the majority of other berries of the genus *Rubus* are usable as industrial raw material; thus, their ratio of acids to sugars content is fairly important for fruit palatability.

The content of organic acids in the representatives of the genus *Rubus* under investigation was the highest in raspberries – 1.8% on the average (Kelt *et al.,* 1997). Nestby (1978) research demonstrated that darker berries are more acid than lighter berries and the higher content of soluble solids decreased the acid taste in berries. In blackberries, the content of organic acids is 2–4 times smaller: 0.5-0.8% (Kelt *et al.,* 1997*;* Libek *et al.,* 2003). The acid content of arctic bramble is the lowest if compared to the above-mentioned species, remaining within 0.2–0.3% (Starast *et al*., 2000). Arctic brambles growing in Finland are notably more acid (0.3-1.9%) (Häkkinen *et al.,* 1994). At the same time, it has been found that the arctic bramble fruits of hybrid cultivars contain more acids than artic bramble fruits, thus, it can be concluded that the origin of the cultivar is important (Häkkinen *et al.,* 1994; Starast *et al*., 2000). Among hybrid

cultivars, Aura and Astra are with smaller sugar content and less aromatic. The fruits of arctic bramble and hybrid cultivars are with different biochemical composition (Häkkinen *et al*., 1994; Starast *et al*., 2000).

The content of ascorbic acid in berries is variable and related to fairly various conditions: year, growth area, and cultivar properties. Thus, ascorbic acids content in arctic bramble has been between 19–50 mg $100g^{-1}$ (Kelt *et al.,* 1997; Starast *et al*., 2000). It has been found that blackberry ascorbic acids content is notably lower compared to raspberry – 5 to 38 mg $100g^{-1}$ (Kelt *et al.,* 1997*;* Libek *et al.,* 2003*).* Raspberry is less responsive to growth conditions and that is why the differences between years and growth areas are smaller; thus, the results in respect of ascorbic acids content are more even and its average content is 32 mg $100g^{-1}$ (Kelt *et al.,* 1997). Ascorbic acids content of the raspberry Estonian cultivar is 29 mg $100g^{-1}$. The content was highest in 'Alvi' - 34 mg $100g^{-1}$ (Kikas *et al*., 2002; Arus *et al*., 2008). In Norway, the average ascorbic acids content has been 27.5 mg $100g^{-1}$ and the differences were caused by cultivar properties (Remberg *et al*., 2007).

Cultivation technologies influence on biochemical composition has been less studied. However, in case of strawberries, it has been found that Black Mypex film application reduces titratable acids content (Neuweiler *et al*., 2003). In Estonian conditions, it has been found that growing strawberries using plastic mulch and additional fertilization raises their vitamin C content (Moor *et al*., 2004). The loss of acids is accelerated by increasing temperatures prior ripening (Naumann, Wittenburg, 1980).

2. HYPOTHESES AND AIMS

Arctic bramble plantations are small, where no chemicals are used and natural areas border on plantations. Due to the above mentioned reasons, we hypothesise that there should be enough pollinators for arctic bramble. It can be presumed that in case of early blooming; bumblebees are the usual pollinators that are considered to be fairly effective.

We hypothesise that, since the arctic bramble grows in Estonian nature and has fruited successfully in the Estonian University of Life Sciences experimental garden conditions, it could be suitable to cultivate in Estonian plantations. Therefore, more hybrid cultivars need to be studied in Estonian conditions, since so far experiments only with Finnish cultivars have been conducted.

Also, it is important to investigate cultures' productivity and their cultivation suitability from *Rubus* taxa, by which established plantations would be long lifetime. The choice of the right taxa should give yield despite unfavoured weather conditions.

In earlier experiments, Estonian strain of arctic bramble has given a bigger yield showed good infection resistance than the Finnish one. Thus, we hypothesized that Finnish cultivars and Estonian strain combining may increase arctic bramble yield. Since a mixture of different cultivars is grown at plantations for successful pollination, food industry gets a mixture of fruit from several cultivars. The previous investigations have focused primarily on fruit properties of different cultivars, but the amount of variability of yield biochemical characteristics when different cultivars are grown in mixture is still unclear. Although, biochemical composition of the cultivars was different, it could be presumed that the biochemical composition difference of the mixed yield would be less than it has been in earlier experiments where cultivars were compared separately.

Different growing technologies notably influence berry cultures growth and, therefore, we could hypothesise that, using different growing technologies and, thus, influencing vegetative growth of *Rubus* species, we may be able to influence biochemical composition of berries.

The main aims of the present investigation were to find out:

1) who are major pollinators and whether enough pollinators for arctic bramble exist in Estonian plantations conditions;
2) the effect of cultivar properties and cultivation technology on productivity in some selected *Rubus* taxa;
3) suitable Finnish arctic bramble cultivar for cultivation in combination with Estonian strain;
4) arctic bramble fruits biochemical composition and yield colour if analysed as a mixture of two cultivars;
5) the influence of mulching and yielding time on raspberry and blackberry fruits' biochemical composition.

3. MATERIALS AND METHODS

3.1. Experimental sites

The arctic bramble experiments were established in Tartumaa, South-Estonia (**II**, **IV**). The three different experiments were established to investigate the pollinators' behaviour on arctic bramble. The first experimental plot was established in Vasula (1996), the second - in Kambja (1997) and third in the experimental garden of EMÜ (1995) (**II**). The distance between plants within the rows was 30 cm at EMÜ garden and 33 cm at other sites, while the distance between the rows was 1 m at EMÜ and 1.20 m in Vasula and Kambja. At plantations, the rows were covered with a plastic mulch in Vasula and Kambja and with a peat mulch at EMÜ.

In the bramble field experiment, rows of arctic brambles were grown alternately with raspberries (**IV**). Raspberries were planted in 1999 and arctic bramble in May 2000. The experiment was established on Luvisol (Word Reference Base for Soil Resources, 2006) and contained P - 82, K - 267, Mg - 150, B - 0.79, Ca - 1100, Cu - 2.8 mg l^{-1}. The soil pH_{KCl} was 5.6. The experimental plants were planted on a bed with a plastic mulch (black polyethylene with a thickness of 0.06 mm). A drip-irrigation system was placed under the mulch. The distance between plants in the rows was 33 cm.

The experiment with raspberry and blackberry was established in autumn 1999 in EMÜ's experimental garden, where plants propagated from root suckers (**III**) and *in vitro* (**I**) were used. The blackberry cultivar Agawam and Black Satin, raspberry cultivar Tomo and hybrid 'Tayberry' were used. The results of soil analyses were as follows: P content – 141, K – 169, Mg – 64 and Ca – 1580 mg kg^{-1} (Mehlich method was used), organic matter – 2.6%, pH_{KCl} 5.1. The plant density in the experiment was 1.5×2.5 m (plant × row spacing). Black Woven Ground Cover (100g/m^2, UV, 100% Polypropylene) was used as a mulch. The soil in treatments without mulch was cultivated mechanically during the vegetation period in accordance with nesessary requirement. No irrigation system was used in the plantation.

3.2. Experimental variants

In the experiment, where arctic bramble pollinators were studied, E1 is the first cultivated Estonian arctic bramble ssp. *arcticus* strain originating from wild nature. In 1995, the Estonian Ministry of the Environment gave the permission to remove the strain for experiment from its habitat in Kaansoo. The arctic bramble has been a protected species in Estonia since 1958. Alternately planted cultivars were:

- Finnish cultivar Pima,
- Estonian strain from Kaansoo (E1). (**II**)

In the arctic bramble field experiment Estonian strain E1, Finnish arctic bramble ssp. *arcticus* cultivars Mespi, Pima and Susanna were used. Hybrid arctic bramble cultivars Aura and Astra originate from Finland and 'Anna' and 'Beata' from Sweden. There were 72 plants in variant (24 plants in three replications). Taking into consideration the fact that arctic bramble is self – sterile, every variant consisted of 2 cultivars (12+12 plants in replication), which were planted in rows alternately. The following cultivar combinations were used:

- E1+'Susanna';
- E1+'Mespi';
- E1+'Pima';
- 'Astra'+'Aura';
- 'Astra'+'Anna';
- 'Anna'+'Beata'. (**IV**)

Two different cultivation technologies were used in experimental plantation with raspberry and blackberry. The experiment consisted of four variants with three replications:

- raspberry cultivar Tomo without mulch;
- 'Tomo' with mulch;
- blackberry cultivar Agawam without mulch;
- 'Agawam' with mulch. (**III**)

3.3. Sampling and measuring plant status and yield

Data were collected:

- from the arctic bramble pollinators experiment 1999 (**II**);
- from productivity experiments 2001, 2002 (**I**), 2003 (**IV**), 2004 (**III**);
- from arctic bramble cultivars combinations experiment 2001, 2002, 2003 (**IV**);
- from different cultivation technologies experiment 2001, 2002, 2003, 2004 (**III**).

Winter damage was estimated in 2002 using a nine-point scale: 9 point – very low winter hardness, all bushes damaged; 1 point – very high winter hardness, no bushes were damaged. (**I**)

The number of arctic bramble shoots per bush was counted and their length measured (cm). The length of shoots was measured from the ground to the shoot tip. The leaf area (mm^2) was also measured (ADC BioScientific Ltd. Area meter AM100). (**IV**)

The fruiting periods of the arctic bramble were: 26 June - 7 August 2001, 22 June - 8 July 2002 and 27 June - 11 July 2003. In 2004, the yield was harvested only twice. The experiment was carried out until 2005, but in 2004 and 2005 no considerable yield was formed and therefore, these years were not included in the current research. The yield was recalculated for a m^{-2}. Average fruit weight (g) was determined during the harvest. (**IV**)

Every harvest day, the number of drupelets per ripen arctic bramble fruits was determined (**II**, **IV**).

Raspberries were harvested:

- 19 July - 14 August 2001 (5 times);
- 3 July - 16 July 2002 (3 times);
- 12 July - 8 August 2003 (4 times);
- 16 July -6 August 2004 (6 times).

Blackberries were harvested:

- 8 August - 5 October 2001 (7 times);
- 5 August - 12 September 2002 (5 times);

- 13 August - 3 October 2003 (6 times);
- 19 August - 19 October 2004 (7 times).

In every replication were weighted (g) 10 fruits. (**I**, **III**)

3.4. Counting pollinators

The number of various pollinators and their taxonomic attribution were established in Vasula and Kambja plantations (**II**). Pollinators were counted on a 2 m long stretch of row (six replications) after recording the number of the opened flowers. During the flowering period, insects visiting the flowers within a 30 min interval in the morning, at noon and in the afternoon were counted and their species determined. The number of flowers visited by a single pollinator was recorded, as well. The track of a bee on a row was followed from its arrival till the departure from the row. The length of the row covered during one flight was taken as the forage distance.

3.5. Measuring fruit quality

Chemical analyses were made using frozen fruits in January 2001- 2004 (**III**) and 2002-2003 (**IV**). Dry matter (DM) was determined by drying fruits in thermostat (Memmet) to its stable weight (105 °C) (**III**).

Soluble solids (SS) content (SSC) was determined in percentage with the refractometer (ATAGO Pocket Refract meter PAL–1, CO., Ltd., Japan) (**III**, **IV**).

Ascorbic acid (AA) content (AAC) was determined with Tillman's method, where 2 g of fruit material was first pounded and then 1% HCl was added. Afterwards, it was filtered and measured in two replications (each 10 ml, 1 ml 1% KJ and 1 ml 1% soluble starch was added). (**III**, **IV**)

Titratable acids (TA) content was measured by the titration method with a 0.1 N NaOH solution, using phenolphthalein as an endpoint indicator. 5 g of material was weighed, ground and then 100 ml water at 80 °C was added. The mixture was heated for 30 minutes and set aside for 2 hours. Afterwards, the mixture was filtered and three replications of 20 ml each were measured off. Neutralizing method 0.1 N NaOH was used for titration. TA content was expressed as citric acid (mg in 100g fresh fruits). (**III**, **IV**)

The soluble solids and titratable acids (SS:TA) ratio was calculated based on the content of SS and TA (**IV**).

The colour of the filtered and heated 5% berry juice was determined (**IV**). The fruit juice colour was measured using a MINOLTA Chroma meter CR-400. The index numbers used were lightness (L*) and the chromaticity coordinates. The a* indicate colour directions: +a* is the red direction, -a* is the green direction.

3.6. Meteorological conditions

In review of EMÜ agrometeorology observatory June 2004 and August 2001 were the months with most rainfall (Lang, 2001-2002). Precipitation during 2001 was significantly higher than the long-term average (1960–1999). There was little rain in May 2002, October 2002 and 2003 and April 2004. On average, April is the month with least-, and August - with most rainfall in Estonia. Among experimental years, 2002 was the year with the highest temperatures during the vegetation period; 2001 and 2003 had the most fluctuating temperatures. On average, the highest temperatures are recoded in July and August in Estonia. Radiation activity was highest in 2002 and lowest in 2004. (**III**, **IV**)

3.7. Statistical data analysis

Data were analysed by one-way (**I**, **II**, **III**), two-way (**III**, **IV**) analysis of variance ANOVA table. To evaluate significances of difference among variants, the least significant different ($LSD_{0.05}$) was calculated (**I**, **III**, **IV**); also the standard error was determined (**I**). To find out relationships among different parameters correlations, regression analyses and standard deviation (±SD) were applied. The mean (±SE) is presented in figures (**II**). Linear correlation coefficients between variables were calculated; the significance of coefficients being P<0.05*, P<0.01** (**IV**). Significant (p< 0.05) differences were marked by asterisk (*) (**I**) or by letters (a, b, c…) (**III**, **IV**) in tables and figures.

4. RESULTS AND DISCUSSION

4.1. Arctic bramble pollinators and their behaviour

The studied arctic bramble cultivars differed significantly (t=-7.01167, df=22, P=0.000) in the number of flowers at the peak of flowering when 'Pima' had 27 ± 7 and the Estonian clone 40 ± 6 flowers for the plant (**II**, Fig. 1A). The first flowers opened in plantation covered with black plastic mulch in the first half of May already; in the wild where the arctic bramble grows in semi shade in the grass under trees it starts to bloom at the end of May (Reier, 1982; Karp, Starast, 1998; Karp *et al*., 2004). Under favourable conditions flowering lasted the whole summer until September, with a maximum intensity (up to 120 flowers per m^2) in June.

Observations showed that flowers of the arctic bramble were visited during the whole period of intensive flowering mainly by honeybees, who constituted 75% of the total number of pollinators (**II**, Fig. 1B). Honeybee density was highly dependent on flower density. Hover flies constituted 18% and bumblebees only 7% of the visitors on the flowers (**II**, Fig. 1B). Bumblebees visited the plantation at the beginning of May and in June, i.e. at the beginning and at the end of the flowering period of the arctic bramble, not at its full flowering. Anthers in arctic bramble flowers are strongly pressed against each other and warped downward towards the center; therefore larger insects are more efficient pollinators. The density of bumblebees in cultivated and natural habitats is not significantly different (Mänd *et al*., 2002). The phenology of bumblebees and their cast representation on the arctic bramble was closely related the seasonal cycles of colony growth.

The pattern of arctic bramble pollinator communities in Finland is close to our results – there, too, honeybees are the major pollinators of these flowers (Kangasjärvi, Oksanen, 1989). In Estonian plantations the low temperatures strongly affect the number of honeybees, but bumblebees are less affected. It is well known that bumblebees continue to work in the field under weather conditions that deter honeybees from foraging and they work longer hours (Wratt, 1968; Corbet *et al*., 1993). However, bumblebees foraged more quickly in terms of flower visits per minute, carried more pollen on their bodies than bees, and also deposited more pollen on stigmas (Willmer *et al*., 1994).

At the foraging flights 58% of the bees flied no more than 1 m of the row (3 plants) and 23% up to 2 m (**II**, Fig. 2). The amount of bumblebees was affected by the number of flowers in the plantation ($r=0.4$, $n=33$, $P<0.05$) whereas the number of honeybees remained unaffected ($r=0.1$, $P>0.05$).

In our arctic bramble experimental plantation the fruits consisted of 10…37 drupelets each (**II**, Fig. 3; **IV**, Fig. 1B). An average arctic bramble fruit consists of 15-30 single drupes (Reier, 1982). This number may range from 2 to 55 depending on the pollination rate (Ryynänen, 1973). In the case of self-pollination, fertilization does not take place at all, or poor fruits are formed. Formation of normal fruits is an evidence of sufficient pollination having occurred in our experimental plantations. Compared to the arctic bramble cultivars the hybrids had a higher number of drupelets (**IV**). The hybrids 'Astra' and 'Aura' had the highest number of drupelets. E1 and 'Susanna' fruit mix had the lowest number of drupelets. In 2001, there was significantly more drupelets compared to other years. In the current experiment, drupelets number indicated that the pollination was not very successful, however, hybrid cultivars were better pollinated. In addition to cultivars characteristics, pollination success and presence of pollinators is greatly dependent on yearly climatic conditions. The reason for the greater number of drupelets in 2001 was possibly the larger amount of precipitation in summer that increased the moisture content in air (**IV**, Table 1).

As the arctic bramble is an insect-pollinated plant, the grower has to consider the behaviour of pollinators when choosing the planting distance between cultivars. Bees moved along a row choosing nearest flowers irrespective of the cultivar. At the same time all bumblebees prefer flowers that offer abundant nectar, because they are large insects with a high energy requirement, both for flight and for the muscular effort (Heinrich, 1979). Bumblebees prefer black currants and raspberries; they visit flowers of red currant and gooseberry less often (Mänd *et al*., 1996). Therefore cultivars characterized by abundant flowering ought to be planted alternately with other cultivars, one plant of the first cultivar between every 1 to 2 plants of the other one. Similarly with our findings, other researchers have stated that pollinators moved along the rows; 62% of the foraging flights were limited to one plant, 34% were made between plants of the same row, and only 37% of the flights occurred between the rows (Kangasjärvi, Oksanen, 1989).

4.2. The effect of *Rubus* taxa cultivar properties and cultivation technology on productivity

The results have shown that the winter damage of blackberry cultivar Agawam was not very large but 'Black Satin' was less winter hardy (**I**, Fig 4B). The 'Tayberry' had average winter damage, 5 points. The study showed that the blackberry cultivar Agawam had good winter hardiness, but cultivar Black Satin was unsuitable for Estonian climate. Winter hardiness is one of the most difficult problems for blackberry growers (Selonen, Tigerstedt, 1989). Blackberry canes are injured at temperature below -23 °C (Moor, Skirvin, 1990).

The yield of blackberry 'Agawam' was 2.7 kg per bush and 6.0 t ha^{-1}, of 'Black Satin' it was 2.6 kg per bush and 5.9 t ha^{-1} (**I**, Fig. 4A). The yield of 'Tayberry' from a bush was 1.1 kg and 2.5 t ha^{-1}. The results from present experiment showed that the yield per bush of blackberry cultivar Agawam could be 2-5 kg. From previous experiments the highest yield obtained from cultivar Agawam bush was 1.67 kg and the average yield was 0.88 kg (Parksepp, 1977).

Cultivation technology did not influence raspberry and blackberry fruit weight in any of the experimental years (**III**, Table 3). Experimental year had significant influence on raspberry and blackberry fruit weight. Though the significant influence of cultivation technology on fruit weight was not observed in present study; however, the tendency of mulch to increase fruit weight was noticed. It has been found in other studies, that plastic film increases raspberry fruit weight in first yield, but when the plantation ages, fruit weight decreases (Percival *et al*., 1998; Kikas *et al*., 2002).

The reason, why effect of mulch did not appear in our experiment, could be related to soil characters in experimental area. Stagnic luvisol with sandy loam texture is known to have great water holding ability and therefore differences between growing conditions with and without mulch are smaller.

Yielding time influenced fruit weight of both studied *Rubus* species: fruits picked at the first part of the yielding period were heavier (**III**, Table 3). The exception was raspberry in 2003, when fruits from first harvest were lighter than fruits from last pick. Mentioned exception could be caused by long and cool spring and little precipitation in June, when fruit ripening begins in Estonia. Thus we may say that one precondition for getting high yields in Estonian unstable weather conditions is additional irrigation. Experiments in Latvia showed that raspberry 'Polana' fruit weight increased up to 47.1% by irrigation (Buskiené, Petronis, 2000). Another possibility could be floricanes shortening and tops cutting of primocanes in different height and time (Jaama, 1960 and 1962; Strick, Cahn, 1999; Himelrick *et al*., 2000; Carew *et al*., 2000).

The arctic bramble fruit weight ranged from 0.6 to 1.2 g, depending on the cultivars combination (**IV**, Fig. 1A). All hybrid cultivars had heavier fruits than arctic bramble cultivars. Heavier fruits were found in hybrid cultivar combinations 'Astra'+'Aura' and 'Anna'+'Beata'. The productivity of experimental plants was highly variable - the yield ranged from 17 to 91 g m^{-2} (**IV**, Fig. 1C). The hybrid cultivars Astra and Aura had significantly higher productivity than other cultivars. The yields of arctic bramble were shown to be significantly lower than those of the hybrid cultivars. In the current experiment, the highest yield of the three experimental years was in arctic bramble hybrid cultivar combinations 'Astra'+'Aura' and 'Anna'+'Beata'. 'Aura' has also shown high productivity in Finnish experiments and has been recommended to grow in combination with 'Astra' (Hiirsalmi *et al*., 1987). At the same time the current experiment indicated that 'Astra' is not the best combination for 'Anna', because the yield was lower than in the combination 'Anna'+'Beata'. In Finnish experiments 'Anna' has been one of the most productive cultivars among Swedish hybrids (Prokkola *et al*., 2001). After these three yielding years the plants were infected and no significant yield was obtained.

In arctic bramble variants, E1 was used in combination with Finnish cultivars. Although the number of drupelets and fruit weight was different between variants, there were no significant differences in yield (**IV**). Cultivar Susanna had not been used in experiments in Estonia before, but based on the current research results 'Susanna' can give the same amount of yield as 'Pima' and 'Mespi'. Thus, if we want to choose a pollinator cultivar for the Estonian local clone, none of the Finnish cultivars from the current experiment can be preferred based on yield.

Correlation analysis showed a positive relationship between arctic bramble yield and drupelets number (r=0.76**), between the fruit weight and drupelets number (r=0.74**), between yield and fruit weight (r=0.82**) (**IV**).

4.3. Biochemical composition and colour of arctic bramble fruits

4.3.1. Biochemical composition

SS content of arctic bramble fruits ranged from 6.6 to 7.5% and was significantly dependent on the cultivars and year (**IV**, Fig. 2A). There were no differences between SS content of hybrid cultivars. The averages of the three experimental years showed that the SS content in arctic bramble fruits varies, even if the fruit are picked from a two-cultivars mixture. The highest SS content was found from fruits in combinations E1+'Susanna'. No significant differences in SS content were found comparing arctic bramble cultivars with hybrid cultivars. These results are different from those of previous experiments, where lower SS content occurred in fruits of hybrid cultivars (Häkkinen *et al*., 1994), with significant differences between the cultivars (Karp, 2001). Previous experiments showed that lower SS content was found in fruits of 'Aura' and 'Astra' (Häkkinen *et al*., 1994; Starast *et al*., 2000). The significant effect in current experiment could be caused by the habitat as well as microclimatic conditions. In other words, the arctic bramble plants were surrounded with raspberries, which offered partial shadow, reduced the temperature fluctuations during the fruit ripening period.

The TA content of arctic bramble fruits ranged from 0.27 to 0.48% during the experimental years (**IV**, Fig. 2B). The 'Astra'+'Anna' fruit mix contained more acids, whereas Hiirsalmi *et al*. (1987) recorded that 'Astra' had more acid fruit. TA content in other hybrid variants was similar to arctic bramble cultivars. Previously conducted experiments have shown that hybrid cultivars produce more acidic fruits (Häkkinen *et al*., 1994; Starast *et al*., 2000; Karp, 2001). The average TA content in fruits in the current experiment was relatively low yet similar to results presented from Finland, showing citric acid content to be 0.3 to 1.9% (Häkkinen *et al*., 1994). In addition to partial shadow, the results were influenced by plant growth. Plant height has a considerable effect on TA content. The highest TA content was found in fruits of plants with a lower, shrub-type growth. The proposition could be that the effect on results obtained here was due to different light conditions.

SS:TA ratio of arctic bramble fruits was influenced by cultivars (**IV**, Fig. 2C). The ratio was significantly higher in strain E1 and 'Susanna' if compared to the hybrid cultivar combinations containing cultivar Astra. TA content was lowest and SS:TA ratio in fruits was higher in 2002. Based on the SS:TA ratio the sweetest fruits in the current experiment were in variant E1+'Susanna'. The important indicator here is the consumers' sense of taste; the higher the SS:TA ratio the sweeter the taste, while the lower the ratio the sourer the taste of the fruits (Haffner *et al*., 2002).

The AA content of arctic bramble ranged from 12 to 19 mg $100g^{-1}$ (**IV**, Fig. 2D). E1 combinations with 'Susanna' and 'Mespi' had significantly higher AA content. Correlation analysis showed a negative correlation between fruit weight and AA (r=-0.67**), shoot number and AA (r=-0.65*) and between the TA and shoot length (r=-0.58*). The average AA content in arctic bramble fruits over the experimental was lower than found in previous experiments conducted in Estonia, which showed AA content to be 19–25 mg $100g^{-1}$ (Starast *et al*., 2000). Differences could be caused by partial shading by raspberries or different annual climatic conditions. Since July was the warmest month during all three experimental years it could have caused the decrease of AA in fruits (**IV**, Table 1). The AA content in the current experiment was also dependent on the fruit weight and the shoot number; the AA content was higher in the case of lower fruit weight and shoots number.

4.3.2. Fruits colour

Significantly higher L* values of fruit juice were found in the E1 combination with 'Mespi' or 'Pima' (**IV**, Fig. 3A). Significantly lower +a* values were found in E1 and 'Pima' mixes (**IV**, Fig. 3B). Darker juice was obtained from hybrid cultivar combinations where 'Astra' was used.

The correlation between drupelets number and L* (r=-0.56**) was negative (**IV**). A positive correlation was found between the drupelets number and a* values (r=0.55**), also between AA content and L* (r=0.57**). A positive correlation was found between the leaf area and a* values (r=0.56*), but there was a negative correlation between the shoot number and L* (r=-0.57*).

The presence of an intense red colour is important in arctic bramble, which is a valuable raw material resource for liqueur production. The current results showed that cultivar Astra improves the colour of cultivars mixture fruits. 'Astra' has also had good colour in previous experiments in Estonia (Starast *et al*., 2000). Among arctic bramble cultivar combinations with the Estonian clone, the juice was darker when 'Susanna' was used in combination. Thus 'Susanna' had the best colour among Finnish cultivars. In the current experiment erratic fruit colouring influenced the arctic bramble fruit juice colour. Most of the fruit was dark red and soft, but 1–3 drupelets remained yellow. Pirinen *et al*. (1998) also noticed this kind of erratic colouring. In the current experiment however, the erratic fruit colouring did not occur on hybrid cultivars. Moreover, correlation analysis showed that arctic bramble drupelets number significantly influenced the colour; the more drupelets present, the darker and redder the fruit.

4.4. The influence of mulching and yielding time on raspberry and blackberry fruits' biochemical composition

Raspberry and blackberry fruit DM content was not influenced neither by cultivation technology either by experimental year (**III**, Table 4). Yielding time had significant influence on fruit DM content, but the influence was yearly different. Average DM content in raspberry and blackberry was at the same level despite of different species. Raspberry DM content in present study was higher than previously recorded in Norway, where different raspberry cultivars had average DM content of 14.6% (Haffner *et al*., 2002). DM accumulation and production in fruits is directly related to climatic conditions and especially with root-zone temperature (Boynton, Wilde, 1959; Percival *et al*., 1998). Relation of DM accumulation with temperature was especially clearly noticed in 'Agawam' in summer 2002. Influence of yielding time on DM content appeared mostly in raspberry. One influencing factor could be plant age, since *Rubus* plants have two - year's life cycle and after plants have had yield, water movement in plants is going to slow down.

Raspberry fruit SSC was significantly different in variants with mulch and without it in 2001 and 2003 (**III**, Table 5). Blackberry fruit SSC was significantly influenced by cultivation technology in 2001. In the present experiment SSC was higher in fruits from plants grown without mulch. Yielding time had no effect on raspberry fruit SSC, but had influence on blackberry fruits. Experimental year influenced SSC; the highest SSC in raspberry and blackberry was found in 2002. Experiments with strawberries have also shown that groundcover did not increase SSC, even though sprinkling irrigation was used (Neuweiler *et al*., 2003). We may say that with cultivation technology we can also influence content of total sugars in raspberries and blackberries, because earlier experiments have shown that SSC in fruits is linearly related to the content of total sugars (Kallio *et al*., 2000; Gonzales *et al*., 2002). Influence of yielding time was only noticed on blackberries, where SSC was significantly higher in fruits from first harvest Mentioned finding could be related to fruit weight, which was also greater at the beginning of yielding season. Similarly with the results of fruits DM content, the relation between SSC and experimental year through climate was noticed in our experiment. It has also been recorded about other berry cultures that SSC is affected by environmental conditions (Shaw, 1990).

Raspberry fruit AAC was significantly different in variants with mulch and without it in 2002 and 2003 (**III**, Table 6). Blackberry fruit AAC was not influenced by cultivation technology. Yielding time had an effect on AAC in both berries only in 2004, but whereas raspberry fruit contained more AAC at the beginning of harvesting period, blackberry fruits were richer in AAC at the end of yielding season. Experimental year influenced raspberry AAC, which was significantly higher in 2004 and significantly lower in raspberry in 2001 and in blackberry in 2002. It has been found before that species and cultivars have an effect on AAC (de Ancos *et al*., 1999). AAC in our experiment depended significantly on year, which indicates that weather conditions influence AAC in berries. In our experiment AAC of fruits ranged from 8.6 to16.9 mg in blackberries and from 24.4 to 45.6 mg in raspberries, thus being lower if compared to Estonian average. This can be explained by the fact that AAC in our experiment was determined from prior frozen fruits. Freezing experiments have shown that fruits preserve 78 to 88% ascorbic acid compared to fresh fruits (Kampuse *et al*., 2002). Besides above mentioned, experiments with strawberries have shown that light intensity and temperature are the most important parameters in determining the final vitamin C content. The higher light intensities and cooler temperatures tend to increase the content of vitamin C (Lee, Kader, 2000). The reason could be different growth habit of raspberries and blackberries compared to strawberry: plants are higher and fruits are situated between the leaves, being partially shadowed by them, which could decrease influence of radiation activity.

Raspberry and blackberry fruit TA content was not influenced by cultivation technology, but blackberry fruits contained considerably less TA than raspberry fruits (**III,** Table 7). Influence of yielding time on raspberry fruit TA content did not appear until the last experimental year, whereas

blackberry was more influenced by yielding time: in 2001 and in 2002 fruits from first pick contained more and in 2004 less TA. TA content of raspberry fruits in our study ranged from 1.5 to 2.1%, which was similar to results from the experiments carried out in Spain and Norway (1.7 to 2.3%) (Gonzales *et al*., 2002; Haffner *et al*., 2002). Average TA content in blackberry fruits in the present study was 0.34 to 0.53%. The reasons for variations in TA are told to be cultivar characteristics and weather conditions (Haffner *et al*., 2002; Krüger *et al*., 2003). Yielding time also had significant influence on TA content in blackberry fruits. Experiments with strawberries have shown that TA content is higher with lower fruit set (Lenz, Buenemann, 1967), which explains also our 2001 and 2002 years' results. Higher content of TA in 2003 and 2004 could be explained by plantation aging and also weather.

CONCLUSIONS

On the basis of investigations at arctic bramble plantations, honeybees are the major pollinators. Honeybees make their foraging flights along the rows, and in a young plantation the foraging distance does not usually exceed 1 m. The share of bumblebees and hover flies in pollination is much less significant. Hybrid cultivars flowers were better pollinated, than those of arctic bramble cultivars. However, the pollination success depends on factors including the weather, foraging area, state of the nest. Our experiment showed that there exist enough pollinators in South-Estonian environment, which preserves its natural equilibrium. That is why there is no need for additional supply of pollinators at plantations. (**II**)

The experimental results showed that productivity of *Rubus* taxa are significantly related to cultivar as well cultivars combination but also to the year. Based on present experiment results it is possible to say that blackberry cultivar Agawam, which forms thorns, has high winter hardiness and high yielding, because of that it could be recommended for usage at local plantations. Although, neither herbicides nor pesticides were used, blackberry cultivar Agawam yield was high. The hybrid 'Tayberry' had satisfactory winter hardiness but rather low productivity. The cultivation of non-traditional berry cultures, which are known by relatively good pest resistance and low-input cropping systems, will eventually facilitate the sustainable agricultural systems distribution. In Northern countries with unstable weather conditions, it is important to choose the right cultivation method in order to get fruits of optimum size, good taste and overall high quality. (**I**, **III**)

Arctic bramble hybrid cultivar combinations showed that cultivars originating from the same country should be grown together for ensuring higher yields – good combinations were 'Astra'+'Aura' (Finnish hybrid) and 'Anna'+'Beata' (Swedish hybrid). The main problems for cultivating are damages by spring night frosts and downy mildew. Therefore, it is important to continue the research with arctic bramble in order to find out disease resistance of cultivars, since, in the current experiment, yield could only be received during the first three years. The results of the current research showed that arctic bramble is not suitable for commercial cultivation. (**IV**)

Cultivation technology did not influence raspberry and blackberry fruit weight. Based on research results, we may conclude that in raspberry and blackberry cultivation, mulch use during the first yielding years enables to get larger fruits. Harvesting time had an impact on both species fruit weight. (**III**)

All tested Finnish arctic bramble cultivars are suitable for growing in combination with Estonian clone, but E1 and 'Susanna' fruits had better quality: they had higher soluble solids and ascorbic acid content as well soluble solids and titratable acids ratio. Also this combination produced the darkest juice. (**IV**)

The biochemical composition of a mixture of two arctic bramble hybrid cultivars was different only in titratable acids and ascorbic acid content. The titratable acids content was significantly higher in fruits of combination 'Astra' and 'Anna'. Colour of the hybrid mixture was improved when 'Astra' was used. (**IV**)

By choosing the right cultivation technology, it is possible to influence raspberry and blackberry biochemical composition, first of all soluble solids content. In addition, cultivation technology influences raspberry fruits ascorbic acid content. We may suggest that fruits from plants grown without mulch contain more soluble solids and ascorbic acid. Harvesting time had an impact on both the raspberry and the blackberry fruit dry matter content, but the influence on fruit soluble solids, ascorbic acid and titratable acids content was significant in case of blackberry. The year had a greater effect on the blackberry fruits' titratable acids content. Based on the example of the *Rubus* taxa, we can affect the yield and fruit biochemical composition with agrotechnical measures and, thereby, assure fruits of a higher quality. Therefore, it is important to continue experiments with different growing technologies in order to increase berries' health beneficial and taste properties and, thereby, improve competitiveness of the local products at Estonian market. (**III**)

References

Anon. 1999. Mesimarjan ja jalomaaraimen viljely. Kvarkenrådet, Vasa: 48 s. (In Swedish and Finnish).

Arus, L., Kikas, A., Libek, A., Kaldmäe, H. 2008. Testing five raspberry cultivars of Estonian origin. Acta Hort. 777: 161-166.

Boynton, D., Wilde, H.M. 1959. Development of the black raspberry fruit. Seasonal increases in gross volume, dimension and dry weight. Proc. Amer. Soc. Hort. Sci. 73: 158–163.

Buskiené, L., Petronis, P. 2000. Irrigation effect on growth and productivity of autumn raspberry cultivar 'Polana'. Fruit production and fruit breeding, Proceeding of the International Conference, EAU: 177–180.

Carew, G.J., Gillespie, T., White, J., Wainwright, H., Brennan, R., Battey, N.H. 2000. Techniques for manipulation of the annual growth cycle in raspberry. J. Hort. Sci. Biotechnol. 75(5): 504–509.

Corbet, S. A., Fussel, M., Ake, R. Fraser, A., Gunson, C., Savage, A., Smith, K. 1993. Temperature and the pollinating of social bees. Ecological Entomology 18: 17–30.

Crandall, P.C., Allmendinger, D.F., Chamberlain, J.D., Biderbost, K.A. 1974a. Influence of cane number and diameter, irrigation and carbohydrate reserves on the fruit number of red raspberries. J. Amer. Soc. Hort. Sci. 99: 524-526.

Crandall, P.C., Chamberlain, J.D., Biderbost, K.A. 1974b. Cane characteristics associated with berry number of red raspberry. J. Amer. Soc. Hort. Sci. 99: 370-372.

Cresswell, E. 2000. A comparison of bublebees' movements in uniform and aggregated distributions of theit forage plant. Ecological Entomology 25: 19–25.

de Ancos, B., Gonzalez, E., Cano, M.P. 1999. Differentiation of raspberry varieties according to anthocyanin composition. Eur. Food Res. Technol. 208(1): 33–38.

Doty, T.E. 1976. Fructose sweetness: a new dimension. Cereal Foods World 21: 62-63.

Eesti punane raamat (Estonian Red Data Book). 1998. Koostaja ja toimetaja Vilju Lilleleht. Eesti Teaduste Akadeemia. Looduskaitse Komisjon. 150 lk. (In Estonian).

EMÜ (Eesti Maaülikool), Estonian University of Life Sciences, Majandus- ja sotsaalinstituut. 2007. Marjakasvatusalase turuinformatiooni kogumine, analüüs ja levitamine. Uurimistöö aruanne. Tellija: Põllumajandus-Kaubanduskoda. 82 lk. (In Estonian).

Estonian Horticultural Association, Eesti Aiandusliit. 2008. Statistika-puuviljad-marjad, Puuvilja- ja marjaksvatus Eestis (http://www.aiandusliit.ee/default.asp?id=157#) (In Estonian).

FAOSTAT. 2008. Food and Agriculture Organization of The United Nations. http://faostat.fao.org/

Finn, C., Knight, V.H. 2002. What's Going on in the World of *Rubus* Breeding? Acta Hort. 585(1): 31-38

Gonzales, M.E., de Ancos B., Cano, M.P. 2002. Preservation of raspberry fruits by freezing: physical, physico–chemical and sensory aspects. Eur. Food Res. Technol. 215: 497–503.

Green, A. 1971. In: Hulme AC (ed.). Soft fruits. The biochemistry of fruits and their products. New York: Academic Press, 2: 375-410.

Gundersheim, N., Pritts, M. 1989. Identifying an appropriate pruning system for 'Royalty' purple raspberry. Acta Hort. 262: 357-364.

Haffner, K., Rosenfeld, H., Skrede, G., Wang, L. 2002. Quality of red raspberry (*Rubus idaeus* L.) cultivars after storage in controlled and normal atmospheres. Postyield Biology and Technology 24: 279-289.

Haffner, K., Vestrheim, S. 1994. Kulturheidelbeeren – Eine neue Beerenproduktion in Norwegen. Erwerbsobstbau 36(7): 184-187.

Halvorsen, B.L., Carlsen, M.H., Phillips, K.M., Bøhn, S.K., Holte, K., Jacobs, D.R. Jr., Blomhoff, R. 2006. Content of redox-active compounds (ie, antioxidants) in foods consumed in the United States. Am. J. Clin. Nutr. 84 (1): 95–135.

Hanni, L., Libek, A. 2003. Occurrence of some raspberry cane diseases depending on different mulching and varieties. Horticulture and vegetable growing 22(3): 382-388.

Heiberg, N. 1999. Effect of raised beds, black soil mulch and oxadixyl on root rot (*Phytophthora fragariae* var. *rubi*) in red raspberry. Acta Hort. 505: 249-258.

Hellqvist, S. 2000. Establishment of Hybrid Arctic Bramble under Field Conditions. Acta Agriculture Scandinavica 50: 169-177.

Hiirsalmi, H. 1975. Berry fruit characteristics in cultural studies. Liitteesta, Koetominta ja Kaytanta 1: 4.

Hiirsalmi, H., Junnila, S., Säkö, J. 1987. Mesimarjan jalostus johtanut tulokseen. Maatalouden tutkimuskeskus. Tiedote 18/87: 9-21 (In Finnish).

Himelrick, D.G., Ebel, C.R., Woods, M.F., Wikins, S.B., Pitts, A.J. 2000. Effect of primocane topping height and lateral length on yield of 'Navaho' blackberry. Small Fruits Review 1(2): 95–101.

Häkkinen, S., Kokko, H., Kärenlampi, S. 1994. Sugar and organic acid in clones and cultivars of arctic bramble and hybrid, sensory evaluation of juices and jellies. Agricultural Science in Finland 4: 385-395.

Inosemzev, V.V. 1992. Eševika v vašem sadu. Lenisdat, Sankt-Peterburg, 95 s. (In Russian).

IUSS Working GroupWRB. 2006. Word reference base for soil resources 2006. 2nd edition. WordSoil Resourses Reports. No. 103. FAO. Rome. 145 p.

Jaama, A. 1960. Ühest vaarikasaagi suurendamise abinõust. –"Sotsialistlik Põllumajandus" 24: 1122-1123 (In Estonian).

Jaama, A. 1962. Veel ühest vaarikasaagi suurendamise abinõust. –"Sotsialistlik Põllumajandus" 12: 556 (In Estonian).

Jennings, L.D. 1988. Raspberries and blackberries: their breeding, diseases and growh. Academic Press, Great Britain, 230 p.

Jensen, K.I.N., Yarborough, D.E. 2004. An overview of weed management in the wild lowbush blueberry - Past and present. Small Fruits Review 3(3-4): 229–255.

Jordan, C.F. 2004. Organic farming and agroforestry: alleycropping for mulch production for organic farms of southeastern United States. Agroforestry Systems 61/62: 79–90.

Jänes, H., Kask, K., Libek, A.-V., Tiirmaa, K., Univer, T. 2006. Eesti puuvilja- ja marjasordid (Estonian fruit and berry cultivars). Eesti Maaülikool põllumajandus- ja keskkonnainstituut, Polli aiandusuuringute keskus, 122 p.

Kallio, H., Hakala, M., Pelkkikangas, A.M., Lapveteläinen A. 2000. Sugars and acids of strawberry varieties. Eur. Food Res. Technol. 212: 81–85.

Kampuse, S., Kampuss, K., Pizika, L. 2002. Stability of anthocyanins and ascorbic acid in raspberry and blackcurrant cultivars during frozen storage. Acta Hort. 585: 507–510.

Kangasjärvi, J., Oksanen, J. 1989. Pollinator behaviour in cultivated and wild Arctic Bramble (*Rubus arcticus* L.). Journal of Agricultural Science in Finland 61: 33–38.

Karp, K. 2001. Agrotehniliste võtete ja sordi mõju mesimuraka (*Rubus arcticus*) ja aedmaasika (*Fragaria* x *ananassa*) taimede kasvule ja saagile. Effect of growing technology and cultivar on growth and yield of arctic bramble (*Rubus arcticus*) and strawberry (*Fragaria x ananassa*). Väitekiri põllumajandusteaduse doktori teaduskraadi taotlemiseks taimekasvatuse erialal. 136 lk. (In Estonian).

Karp, K., Mänd, M., Strarast, M., Paal, T. 2004. Nectar production of *Rubus arcticus*. Agronomy Research 2(1): 57-61.

Karp, K., Starast, M. 1997. The Artic bramble (*Rubus arcticus* L.) – the most profitable berry in Estonia. Baltic Forestry 3(2): 47-52.

Karp, K., Starast, M. 1998a. Domestication of Estonian natural arctic bramble. Forestry Studies XXX, Wild Berry Culture: an Exchange of Western and Eastern Experiences: 70-75.

Karp, K., Starast, M. 1998b. Mesimuraka saagikus ja looduslikud tolmlejad. Teadustööde kogumik. Põllumajanduskultuuride produktiivsus ja kvaliteet 199: 146-149 (In Estonian).

Karp, K., Starast, M. 1999. The suitability of Estonian natural arctic bramble (*Rubus arcticus* L.) for field cultivation. Transactions of Estonian Agricultural University, Agronomy 203: 33-35 (In Estonian).

Karp, K., Starast, M., Kaldmäe, H. 2002. Influence of the age of plants and foliar fertilization on the yield of strawberry cultivar Jonsok under plastic mulch. Acta Hort. 567: 459–462.

Karp, K., Starast, M., Reier, Ü. 2000a. Factors affecting the yield of arctic bramble (*Rubus arcticus* L.) cultivated in Estonia. Problems of rational utilization and reproduction of berry plants in boreal forests on the eve of the XXI century. Proceedings of the International Conference: 158-160.

Karp, K., Starast, M., Tiido, T. 2000b. Frost damages of Arctic Bramble (*Rubus arcticus*) and half-highbush blueberry (*Vaccinium corymbosum x Vaccinium angustifolium)* depend on cultivation methods. Proceedings of the International Conference: Fruit Production and Fruit Breeding: 244–247.

Karp, K., Starast, M., Moor, U. 2006. Kännasmustika sortide ja ahtalehise mustika kloonide võrdlemine. EMÜ, aastaaruanne projektile: „Puuviljade ja marjade viljelemise tehnoloogiate täiustamine toodangu kvaliteedi, säilivuse ja konkurentsivõime tõstmise eesmärgil", 12 lk. (http://www.eau.ee/%7Eaiandus/pdf/2006mustikassort.pdf) (In Estonian).

Karp, K., Starast, M., Moor, U. 2007. Kännasmustika sortide ja ahtalehise mustika kloonide võrdlemine. EMÜ, aastaaruanne projektile: „Puuviljade ja marjade viljelemise tehnoloogiate täiustamine toodangu kvaliteedi, säilivuse ja konkurentsivõime tõstmise eesmärgil", 12 lk. (http://www.eau.ee/%7Eaiandus/pdf/2006mustikassort.pdf) (In Estonian)

Kelt, K., Lamp, L., Piir, R. 1997. Puuviljad Marjad Tervis. Valgus, Tallinn: 230 lk. (In Estonian).

Kikas, A., Libek, A., Hanni, L. 2002. Evaluation of raspberry cultivars in Estona. Acta Hort. 585: 203–207.

Kokko, H., Kärenlampi, S., Rissanen, E., Tammisalo, J., Kärenlampi, L. 1993. EY – markkinakelpoisten tuotteiden etsiminen ja kehittäminen: Mesimarjan uudet kannat. Kuopio: 28 s. (In Finnish).

Kokko, H., Virtaharju, O., Karenlampi, S., Cooke, D., Williams, N. 1999. Downy mildew (*Peronospora rubi*) in *Rubus arcticus*: A threat to commercial derry production in Finland. Acta Hort. 505: 137-141.

Kozinski, B. 2006. Influence of mulching and nitrogen fertilization rate on growth and yield of highbush blueberry. Acta Hort. 715: 231–236.

Krearns, C.A., Inouye, D.W., Waser, N.M. 1998. Endangered mutualisms: The Conservation of Plant-Pollinator Interactions. Annual Rewiew of Ecology Systems 29: 83-112.

Krüger, E., Schöpplein, E., Rasim, S., Cocca G., Fischer, H. 2003. Effects of ripening stage and storage time on quality parameters of red raspberry fruit. Europ. J. Hort. Sci. 68(4): 176–182.

Lang. M. 2001-2002. EMÜ Eerika vaatlusjaama agrometeoroloogiline ülevaade. (In Estonian).

Larsson, G. 1969. Experimental Taxonomy as a Base for Breeding in Northern *Rubi*. Hereditas 63: 283-351.

Larsson, G. 1980. *Rubus arcticus* L. subsp. × *stellarcticus*, a new arctic raspberry. Acta Hort. 112: 143-144.

Lee, S.K., Kader, A.A. 2000. Preyield and postyield factors influencing vitamin C content of horticultural crops. Postyield Biol. and Technol. 20: 207–220.

Lenz, F., Buenemann, G. 1967. Beziehung zwischen dem vegetativen und reproduktiven Wachstum in Erdbeeren (Var. 'Senga Sengana'). Gartenbauwissenschaft 32: 227–236.

Libek, A., Kikas, A. 2000. First year vegetative growth of raspberry as a response to different types of mulching. Proceedings of the International Conference, Fruit production and fruit breeding, EAU: 181–184.

Libek, A., Eskla, V., Hanni, L., Vool, E., Niiberg, T. 2003. Vaarikas aias ja köögis. Maalehe Raamat. 183 lk. (In Estonian).

Lindgvist, H., Koponen, H., Valkonen, J. 1998. *Peronospora sparsa* on cultivated *Rubus arcticus* and its detection by PCR based in its sequences. Plant Dis. 82: 1304-1311.

Luby, J.J., Wildung, D.K., Stushnoff, C., Mansion, S.T., Read, P.E., Hoover, E.E. 1989. 'Northblue', 'Northsky', and 'Northcounrty' Blueberries. Horticultural Science 21(5): 1240-1242.

Luffman M., Buszard, D. 1989. The susceptibility of six red raspberry cultivars and Tayberry to fruit infection by late yellow rust [*Pucciniastrum americanum* (Farl.) Arth.]. Acta Hort. 262: 201-204.

Moor, J.N., Skirvin, R.M. 1990. Blackberry management. In Small fruit crop management (Eds. G. J. Galletta and D. G. Himelrick). Prentice Hall. New Jersey: 214-244.

Moor, U., Karp, K., Põldma, P. 2004. Effect of mulching and fertilization on the quality of strawberries. Agric. and Food Sci. 13: 256–267.

Moore, N. 1993. Adapting Low Upland Mineral Soils for Culture of Highbush blueberries. Acta Hort. 346: 221-229.

Moyer, R., Hummer, K., Finn, C., Frei, B., Wrolstad, R. 2002. Anthocyanins, phenolics and antioxidant capacity in diverse small fruits: *Vaccinium*, *Rubus* and *Ribes*. J. Agric. Food Chem 50: 519–525.

Mänd, M., Bender, A., Kase, K., Martin, A.-J. 1997. Õietolmu koguvate mesilaselaadsete jaotumus konkureerivatel ristikuliikidel. Magistrantide ja doktorantide teaduslike tööde kogumik, Tartu 193: 52–57 (In Estonian).

Mänd, M., Karp, K., Starast, M. 2001. Meemesilase (*Apis mellifera* L.) korjekäitumine mesimuraka (*Rubus arcticus* L.) istanduses. EPMÜ teadustööde kogumik 212: 184-187 (In Estonian).

Mänd, M., Mänd, R., Williams, I.H. 2002. Bumblebees in the agricultural landscape of Estonia. Agriculture, Ecosystems and Environment 89: 69–76.

Mücke, K.H., Rieger, U. 1968. Ans der Garten drinnen und drassen. – München, Südwestverlag, 436 s.

Naumann, W.D, Wittenburg, U. 1980. Anthocyanins, soluble solids and titratable acidity in blacberries as influenced by preyield temperature. Acta Hort. 112: 183-190.

Neuweiler, R., Bertschinger, L., Stamp, P., Feil, B. 2003. The impact of ground cover management on soil nitrogen levels, parameters of vegetative crop development, yield and fruit quality of strawberries. Europ. J. Hort. Sci. 68(4): 183–191.

Nes, A., Hageberg, B., Haslestad, J., Hagelund, R. 2008. Influence of cane density and height on productivity and performance of red raspberry (*Rubus idaeus* L.) cultivar 'Glen Ample'. Acta Hort. 777: 231-235.

Nestby, R. 1978. Yield, berry size and some quality components of raspberry cultivars and cross populations. Scientific reports of the Agricultural University of Norway. Report No.38 vol 57: 12 p.

Nikitina, V.S, Shendel, G.V., Gerchikova, A.Ya, Efimenko, N.B. 2000. Flavonoids from raspberry and blackberry leaves and their antioxidant activities. Pharmaceutical Chemistry Journal 34(11): 596–598.

Osborne, J.L., Clark, S.J., Morris, R.J., Williams, I.H., Riley, J.R., Smith, A.D., Reynolds, D.R., Edwards, A.S. 1999. A landscape-scale study of bumble bee foraging range and costancy, using harmonic radar. Journal of Applied Ecology 36: 519–533.

Paasisalo, S. 1997. Cultivated Blueberries New in Finland. International News Forum for professional Berry Growers 1: 8-9.

Parksepp, J. 1977. Vaarikad. Tallinn, Valgus: 141 lk. (In Estonian).

Pedreros, A., González, I.M., Manosalva, V. 2008. Effect of organic mulching on growth and yield of raspberry cv. Heritage. Acta Hort. 777: 473-476.

Percival, C.D., Proctor, J.T.A., Sullivan, J.A. 1998: Supplementary irrigation and mulch benefit the establishment of 'Heritage' primocane–fruiting raspberry. J. Amer. Soc. Hort. Sci. 123(4): 518–523.

Pirinen, H., Dalman, P., Kärenlampi, S., Tammisalo, J., Kokko, H. 1998. Description of three new arctic bramble cultivars and proposal for cultivars identification. Agricultural and Food Science in Finland 7: 455-468.

Polli Horticultural Research Centre, Estonian University of Life Science, 2008

(http://www.polli.ee/eng/fruit_and_berry_cultivars/raspberries).

Prokkola, S., Valkonen, J., Koponen, H., Luoma, S. 2001. Lehtihomeenkestävien mesimarjakantojen valinta. Pohjoisen Laatumarjat–mansikka, tyrni, mesimarja ja jalomaarain. MTT, Maa- ja elintarviketalouden tutkimuskeskus, Pohjois-Pohjanmaan tutkimusasema, Pohjoisen laatumarjat-hanke: 83–88 (In Finnish).

Reier, Ü. 1982. Murakad. Tallinn. 159 lk. (In Estonian).

Remberg, S.F., Måge, F., Haffner, K., Blomhoff, R. 2007. Highbush blueberries *Vaccinum corymbosum* L., raspberries *Rubus idaeus* L. and black currants *Ribes nigrum* L. –influence of cultivar on antioxidant activity and other quality parameters. Acta Hort. 744: 259-265.

Riaz, M.N., Bushway, A.A. 2007. Compositional analysis of four red raspberry cultivars grown in Main. Journal of Food Quality 19(16): 457-465.

Rincon, A.R., Salas, J.A. 1989. Influence of the levels of N, P, and K on the yield of blackberry. Acta Hort. 199: 183-186.

Ruban, N., Kurlovich, T. 2000. Productivity of nectar of *Oxycoccus macrocarpus.* Problems of Rational Utilization and Reproduction of Berry Plants in Boreal Forests on the Eve of the XXI Century. Proceedings of the Conference 11-15 September 2000, Belarus: 210–213.

Ryynänen, A. 1972. Arctic bramble (*Rubus arcticus* L.) a new cultivated plant. Annales Agriculturae Fennae 11: 170-173.

Ryynänen, A. 1973. *Rubus arcticus* L. and its cultivation. Annales Agriculturae Fennae 12: 1-76.

Sanderson, K.R., Cutcliffe, J.A. 1991. Effect of sawdust mulch on yields of selected clones of lowbush blueberry. Can. J. Plant Sci. 71: 1263–1266.

Selonen, K.R.E., Tigerstedt, P.M.A. 1989. The use of interspecific crosses in breeding winterhardy blackberries in Finland. Acta Hort. 262: 133-140.

Shaw, D. 1990. Response to selection and associated changes in genetic variance for soluble solids and titratable acids content in strawberries. J. Amer. Soc. Hort. Sci. 115: 839–843.

Shoemaker, J.S. 1958. Kutlura jagodnõh rastenii i vinograda. Moskva. 562 s. (In Russian).

Smolarz, K., Mercik, S. 1993. Growth and yielding of highbush blueberry *(Vaccinium corymbosum* L.) in response to long-term (since 1923) differential fertilization. Acta Hort. 346: 193-198.

Starast, M. 1998. Mesimurakas (*Rubus arcticus* L.)- uus marjakultuur Eestis. Dissertatsioon põllumajandusteaduste magistrikraadi taotlemiseks aianduse erialal. Tartu, 92 lk. (In Estonian).

Starast, M., Karp, K., Pae, A. 2000. Organic acid, ascorbic acid and sugar content of arctic bramble depending on variety ant its cultivation place. Journal of Agricultural Science XI(1): 81-87 (In Estonian).

Statistical Office of Estonia. 2002. 2001 Agricultural census.

Strik, C.B, Finn, E.C., Clark, J.R., Bañados, M.P. 2008. Worldwide production of blackberries. Acta Hort. 777: 209-218.

Strick, C.B., Cahn, H.K. 1999: Pruning and training affect yield but not machine yield efficiency of 'Meeker' red raspberry. HortScience 3(4): 611–614.

Tammisalo, J. 1988. Incompatibility classes and fruit set in natural populations of arctic bramble (*Rubus arcticus* L.) in Finland. Journal of Agricultural Science in Finland 60: 327-446.

Teuber, L.R., Barnes, D.K. 1979. Environmental and genetic influences on quantity and quality of alfalfa nectar. Crop Science 19: 874–878.

Tiquia, S.M., Lloyd, J., Herms, D.A., Hoitink, H.A.J., Michel, F.C. 2002. Effects of mulching and fertilization on soil nutrients, microbial activity and rhizosphere bacterial community structure determined by analysis of TRFLPs of PCR-amplified 16S rRNA genes. Applied Soil Ecology 21(1): 31-48.

Vool, E., Noormets, M., Karp, K., Mänd, R., Starast, M. 2003. Pollinators and their foraging behaviour in arctic bramble (*Rubus articus* L.) plantations in Estonia. Integrative approaches towards sustainability in the Baltic Sea Region 15: 481-489.

Vrieling, K., Saumitou-Laprade, P., Cuguen, J., Dijk, H., Joung, T.J., Klinkhamer, P.G.L. 1999. Direct and indirect estimates of the selfing rate in small and large individuals of the bumblebee pollinated *Cynoglossum officinale* L. (*Boraginaceae*). Ecology Letters 2: 331-337.

Wang, S.Y., Chen, C-T., Wang Y.C. Feb. 2009. The influence of light and maturity on fruit quality and flavonoid content of red raspberries. Food Chemistry 112(3): 676-684.

Wang, S.Y., Lin, H.S. 2000: Antioxidant Activity in Fruits and Leaves of Blackberry, Raspberry and Strawberry varies with Cultivar and Development Stage. J. Agric. Food Chem. 48: 140–146.

Warmund, M.R., George, M.F. 1990. Freezing survival and supercooling in primary and secondary buds of *Rubus* spp. Can. J. PlantSci. 70: 893-904.

Whitney, G.G. 1982. The productivity and carbohydrate economy of a developing stand of *Rubus idaeus*. Can. J. Bot. 60: 2697-2703.

Willmer, P.G., Bataw, A.M., Hughes, J.P. 1994. The superiority of bumblebees to honeybees as pollinators: insect visits to raspberry flowers. Ecological Entomology 19: 271-284.

Wratt, E.C. 1968. The pollinating activities of bumble bees and honeybees in relation to temperature, competing forage plants, and competition from other foragers. Journal of Aqicultural research 2(7): 61-66.

Wu, L., Yu, H., Dong, L., Zhu, Y., Li, C., Zhang, Z., Li, Y. 2006. Comparison of mulching treatments on growth and physiology of highbush blueberry. Acta Hort. 715: 237-240.

Zimmerman, M. 1983. Plant reproduction and optimal foraging: environmental nectar manipulation in *Delphinium nelsonii*. Oikos 41: 57–63.

SUMMARY IN ESTONIAN

Perekonna murakas (*Rubus*) mõnede liikide saagikus ja viljade kvaliteet

Eestis on võrreldes 1990. aastate algusega marjakasvatajate arvukus oluliselt vähenenud. EMÜ majandusteadlaste poolt 2007. aastal korraldatud marjakasvatusalases uuringus toodi tootmispindade vähenemise peamiste põhjustena välja: tootjate vähesed kogemused, tootmise mittetasuvus, rahanappus investeeringuteks, tööjõupuudus saagi koristamisel, konkurentsi suurenemine. Lisaks eeltoodule võib Põhjamaades tuua välja saagikao põhjustajana klimaatilisi tingimusi nagu ebastabiilsed talveilmad, kevadised hilisöökülmad, suvised põuad jne. Seetõttu on oluline uurida marjakultuuride kvaliteedi ja saagikuse parandamiseks marjaliike ja -sorte. Samuti on oluline erinevate kasvatustehnoloogiate uurimine ja rakendamine marjakultuuride kvaliteedi ja saagikuse parandamisel.

2005. aastal kasvatati maailmas kõige rohkem vaarikat Venemaal, pamplit aga Serbias (FAO Statistics Division 2008; Strik *et al*., 2008). Eestisse on aedvaarikate sorte introdutseeritud 18. sajandist, kuid intensiivistus see 1945. aastal (Parksepp, 1977), kui tegevust alustas praegune Polli Aiandusuuringute Keskus. Aastast 1964 on Eestis kokku aretatud 6 vaarikasorti (Jänes *et al*., 2006). Jätkuvat huvi vaarikakasvatuse vastu Eestis näitab kasvupinna suurus, mis on marjakultuuride hulgas kolmandal kohal. Aedpamplit on Eestis kasvatatud 20. sajandi algusest, sealjuures kaks sorti - 'Wilsons Early' ja 'Agawam' - on olnud perspektiivsortimendis 50-ndate aastate lõpust (Parksepp, 1977). Siiani puuduvad aga andmed eelnevate liikide vaheliste hübriidide ehk vamplite kohta, mille eeliseks peetakse sordiaretuse tulemusel saadud suuremaid ja transpordikindlamaid vilju ning paremat vastupidavust haigustele (Jennings, 1988; Luffman, Buszard, 1989).

Mesimurakat kasvatatakse kõige enam Soomes (Hellqvist, 2000). Selle marjad on hinnalised eelkõige piiratud geograafilise leviku tõttu, kasvades ainult Põhjamaade jaheda suve ja pika päeva tingimustes. Isesteriilsuse ja putuktolmlemise tõttu on vajalik kasvatada istandikes kõrvuti vähemalt kahte mesimuraka sorti, et saaks toimuda edukas tolmeldamine ja areneksid korralikult välja osaviljad. Kevadel varase õitsemise puhul on peamisteks tolmeldajateks kimalased, keda loetakse mesimuraka õie

ehituse tõttu ka efektiivseimaiks. Mesimurakaistandikud on üldjuhul väiksed ning seal ei kasutata taimekaitse preparaate, mistõttu peaks tolmeldamiseks olema küllaldaselt putukaid. Selle väärtusliku taimekultuuri kasvatamise suurimaks probleemiks Soomes on kujunenud ebajahukaste (*Peronospora sparsa* Berk.) levik, sarnast trendi on täheldatud ka Eesti mesimurakakasvatustes.

Eestis on mesimuraka Kaansoost pärinev kloon olnud, tuginedes varasematele läbiviidud katsetele, Soome sortidest saagikam. Seetõttu võib eeldada, et leides Eesti klooniga koos kasvatamiseks sobiva Soome sordi, on võimalik suurendada taimede saagikust. Saagi värvus ja biokeemiline koostis on mesimuraka olulised kvaliteedinäitajad tulenevalt selle viljade kasutamisest alkoholitööstuse toorainena. Eelnevad läbiviidud katsete tulemused on toonud välja üksikute mesimurakasortide biokeemilise koostise erinevused, mis tootmistingimustes sortide segunemisel võivad aga väheneda.

Käesoleva uurimistöö eesmärkideks oli välja selgitada:

- kes on mesimuraka peamised tolmeldajad ja kas Eesti istandikes leidub neid piisavalt;
- mõne *Rubus* perekonna liigi sordiomaduste ja kasvatustehnoloogia mõju saagikusele;
- Eesti mesimurakaklooniga kooskasvatamiseks sobiv Soome sort;
- mesimuraka sordiomaduste mõju viljade biokeemilisele koostisele ja värvusele;
- multši ja saagi koristusaja mõju vaarika ja pampli viljade biokeemilisele koostisele.

Tulemused ja järeldused

Katsetes mesimurakaga selgus, et õite peamisteks tolmeldajateks on meemesilased, kes moodustavad 75% kogu tolmeldavate putukate hulgast. Oma korjelende teostavad meemesilased piki taimeridu ning noores istandikus ei ületa üks korjelend üle 1 m pikkust. Seega on vajalik istutada erineva sordi taimed ühte ritta nii, et sortide vaheldumine toimuks vähemalt ühel meetril. Kimalaste ja sirelaste osatähtsus tolmeldajatena oli väiksem, kusjuures kimalaste arvukus oli suurem õitsemise alguses ja lõpus. Kimalased on nõudlikumad tolmeldajad eelistades taimi, mille õitest saab nektarit lihtsamini kätte. Osaviljade arv sõltub oluliselt tolmeldamise edukusest, mis antud töös jäi vahemikku 10-37. Osaviljade arvu põhjal võib järeldada, et katses olid paremini tolmeldatud mesimuraka hübriidsortide õied. Uurimistöö tulemustele tuginedes võib välja tuua, et Lõuna-Eesti tingimustes on mesimurakale piisavalt tolmeldajaid, kuid sealjuures on oluliseks tolmeldamise edukuse teguriks ilmastik. (**II**, **IV**)

Pamplisort 'Agawam' on kõrge saagikusega ja hea talvekindlusega ning sobib seetõttu kasvatamiseks Eesti tootmisistandustes. Nimetatud sort on uuesti Eesti puuvilja- ja marjakultuuride soovitussortimendi nimekirjas. Arvestades asjaolu, et antud uurimustöö käigus taimi mineraalväetistega ei väetatud, oli saagikus taime kohta (2,7 kg/põõsa kohta) kõrge, seetõttu on vaatlusalune pamplisort eriti sobilik kasvatamiseks mahetootmise tingimustes. Ogadeta pamplisort 'Black Satin' pole vähese talvekindluse tõttu Eesti tingimustesse sobilik. Vampel 'Tayberry' on küll rahuldava talvekindlusega, kuid madala saagikusega liik, mistõttu on vähe sobiv kohalikesse istandustesse. Kasvatustehnoloogia ei mõjuta vaarika ja pampli saagikuse näitajaid, kuid katsetulemustest võis täheldada, et multši kasutamisel on märgata tendentsi saada raskemaid viljasid. Oluline mõju oli aga aastakäigul vaarika ja pampli viljade massile. Mesimuraka saaginäitajate kohta võib öelda, et liikidevahelistel hübriidsortidel olid oluliselt raskemad viljad kui mesimuraka sortidel. Mesimuraka hübriidsortidest olid kõrge saagikusega kombinatsioonid, kus kasvatati koos sama päritolumaa sorte – Soome 'Astra' ja 'Aura' ning Rootsi 'Anna' ja 'Beata'. (**I**, **III**, **IV**)

Katsetulemustest selgus, et mesimuraka Eesti kloonile sobivad saagikuse seisukohalt tolmuandjateks kõik katses olnud Soome sordid: 'Pima', 'Susanna' või 'Mespi'. Biokeemilise koostise osas saadi paremad tulemused Eesti klooni ja sordi 'Susanna' segaviljadest, mis sisaldasid rohkem mahla kuivainet ning kuivaine ja happe suhe oli suurem. Samuti oli nimetatud sortide segaviljade mahl kõige intensiivsema värvusega. (**IV**)

Mitmete parameetrite osas oli mesimurakasortide kombinatsioonide saagi biokeemiline koostis erinev. Hübriidsortide viljade biokeemilises koostises esinesid olulised erinevused tiitritavate hapete ja askorbiinhappe sisalduses. Tiitritavate hapete sisaldus oli oluliselt kõrgem kombinatsioonis 'Astra' ja 'Anna', askorbiinhappe sisaldus aga kombinatsioonis 'Anna' ja 'Beata'. Soome sort 'Astra' parandas hübriidide kombinatsioonides mahla värvust (lisades värvusele tumedust). Käesolevas töös käsitletud mesimuraka kasvatustehnoloogia, kus taimed istutati vaheldumisi vaarikaridadega, andis küll varasematest katsetest oluliselt paremaid tulemusi, kuid ainult

katse esimesel kolmel aastal. Taimede nakatumise tõttu ebajahukastesse on oluline jätkata uuringuid mesimurakasortidega, et leida haiguskindlamaid sorte. Käesoleva töö tulemustest lähtudes võib järeldada, et mesimurakas ei sobi tootmisistandusse Eestis. (**IV**)

Erinevate kasvatustehnoloogiate rakendamisega on võimalik mõjutada vaarikaviljade biokeemilist koostist, eeskätt mahla kuivaine- ja askorbiinhappesisaldust, multšide kasutamine suurendas mõlema nimetatud näitaja sisaldust. Kasvatustehnoloogia mõjust pampli viljade biokeemilisele koostisele võis täheldada tendentsi, et multšita kasvanud saagis sisaldub rohkem kuivainet ja mahla kuivainet. Kuivaine sisaldust mõjutas oluliselt nii pampli kui vaarika korjeaeg. Pampli puhul mõjutas korjeaeg ka askorbiinhappe sisaldust, kusjuures oluliselt vitamiinirikkamad olid viljad saagiperioodi lõpus. Pampli viljade hapete sisaldust mõjutas aga oluliselt aastakäik. Käesoleva uurimistöö tulemustest selgus, et marjade biokeemilist koostist ja ka maitset saab mõjutada kasvatustehnoloogiliste võtetega. Seega vajab edasist uurimist, missugune kasvatustehnoloogia võimaldab meil toota tarbija jaoks tervislikumat ja maitsvamat ning tootja jaoks konkurentsivõimelisemat marja. (**III**)

I

ORIGINAL PUBLICATIONS

Noormets, M., **Vool, E.**, Karp, K., Värnik, R., Starast, M. 2003

NEW TRENDS IN DEVELOPMENT OF ESTONIAN BERRY PRODUCTION TOWARDS TO SUSTAINABLE AGRICULTURE

Integrative approaches towards sustainability in the Baltic Sea Region, 15: 467-473

New Trends in the Development of Estonian Berry Production towards Sustainable Agriculture

M. Noormets[1], E. Vool[1], K. Karp[1], R. Värnik[2], M. Starast[1,3]

[1]Institute of Horticulture
[2]Institute of Agricultural Economy and Marketing
Estonian Agricultural University
Kreutzwaldi 64, Tartu, EE- 51014
Estonia

[3]University of Tartu, Institute of Botany and Ecology
Lai St. 40, Tartu, EE-51005
Estonia

Summary

The situation in agriculture in Estonia has changed a lot during the last ten years. After the old farmsteads were returned to farmers, the number of small farms increased and created suitable conditions for the development and prevalence of berry cultivation. Small farms are mainly located in the areas that are economically undeveloped. To build up those regions there is a need to support activities that would provide income. At present the grain and livestock farming in small areas is not profitable. Nowadays we have many berry growers and the numbers are increasing.

The aim of the present study was to determine regions that are economically less well developed and where the situation could be changed with berry cultivation. Also, to identify the trends in berry species production areas and to study the productivity of less known berry cultures and to investigate their suitability for cultivation, as well as the proper environment friendly technologies for small businesses. The cultivation of non-traditional berry cultures, which are known by relatively good pest resistance and low-input cropping systems, will eventually facilitate the sustainable agricultural systems distribution.

Introduction

After big changes in the Estonian political situation, new challenges emerged in all fields of the economy including the ordinary life of rural habitants. Also, in agriculture major changes took place after the collapse of one system in the 1990's. However, there are going to be more changes when Estonia joins the European Union.

In accordance with ownership reform, unlawfully expropriated land was returned to its legal successors and that caused an increase of small farms, which became interested in the development and prevalence of berry cultivation. There were 54,878 farms in 2001, with a size of 10 hectares of land (Statistical Office of Estonia, 2002). Small-sized farms as production farms have low competitiveness, also grain and livestock farming in small areas is not profitable. Our farmers have difficulties in competing in the domestic and foreign market, so it is important to increase competitive ability by finding new possibilities and solutions. Moreover, if different berry crops are grown in combination on small farms it could provide more economic use of special capital, increase employment in rural areas and ensure sufficient annual income for a farm family.

In order to offer additional options to the existing berry crops, the present study is an attempt to investigate new berry cultures that have low fertilization need, good pest and disease resistance. These qualities would enable environment friendly cultivation of berries. Blueberries (*Vaccinium* sp.) grow well on sandy, acid soils with plenty of summer moisture. High organic matter content is intrinsic in the soils, but the nutrient content may be lower than for most other crops. The optimum soil acidity level for blueberries is between 4.0 and 5.5. They do not grow satisfactorily in alkaline or neutral soils (Smolarz, Mercik, 1993). The suitable soils for blueberry growing are in South Estonia where the climate conditions are also favourable. In Estonia there are 22,000 to 24,000 hectares of opencast peat pits, which have been damaged by peat mining. One way of using these abandoned areas is to recultivate them with species the natural growth habitat of which would be similar to exhausted peat fields. The cultivation of blackberry (*Rubus fruticosus*) is a new trend in Estonian berry cultivation. However, berry cultivation has its own risks and these are mainly related to weather conditions. Also, it is important to know cultivars so that established plantations would have long life expectancy. The choice of the right taxa should give a yield despite unfavourable weather conditions.

The purposes of the present study were to determine regions that are economically less developed and where the situation could be changed with berry cultivation. Also, to identify the trends in berry species production areas and to study the productivity of less known berry cultures and investigate their suitability for cultivation, as well as the proper environment friendly technologies for small businesses.

Materials and Methods

The earning ratio was calculated based on the ratio of actual total income to the standard wage fund and standard income. Based on the questionnaire carried out among producers in 2002, current berry species cultivation was estimated and the trends (1998-2005) in berry production areas (in hectares) were identified.

The production experiments were carried out in the southern part of Estonia during 1998- 2001. The experimental variants were:

- *lowbush blueberry* (*Vaccinium angustifolium*) on peat soil (opencast peat pits)- 1) 4 years old plants, 2) 7 years old plants;
- *half-high blueberry* (*V. corymbosum* x *V. angustifolium*) Northblue cultivar on mineral soil (plantation was five years old)- 1) without mulch, 2) peat mulch, 3) sawdust mulch, 4) plastic mulch 5) mineral soil+peat with peat mulch, 6) mineral soil+peat with plastic mulch;
- *blackberry* (*R. fruticocus*.) – cultivars Agawam and Black Satin, 2) hybrid *Tayberry*

The 4 years old lowbush blueberry plants were planted on opencast peat pits with spacing 0.5 x 0.5 m.; 7 years old plants had a spacing 0.6 x 0.6 m. The plantation was established in 1998. The measurements were taken from bush yield (in grams) and the yield per hectare was calculated on the basis of that. For the half-high blueberries the gap between the plants was 0.7 m and the space between two rows was 1.5 m. After plantation the soil acidity was pH_{KCl} 5.7 in the field. A plantation was founded in June 1997 with one-year-old *in vitro* plants. Mulch treatments were applied in a 70 cm-wide band centred on the plant row immediately after planting. The ground was covered with a 5 cm layer of peat or sawdust mulch. The yield was harvested in August of year 2002 and the yield of every plant was weighted. The study with *Rubus* taxa was established in spring 1999 where the *in vitro* propagated plant material was used. Plant ranges were covered with ground cover (later just with mulch in figures). The experiment was established in 3 replications (5 plants in every plot) with distances between bushes of 1.5 × 2.5 m. The experimental data were collected in 2001 and 2002. Fruits were picked during the harvest period once a week in the 2001 from 19.07 to 5.10 and 2002 from 3.07 to 4.09. Winter damage was estimated in 2002 using a nine-point scale (9 point – very low winter hardness, all bushes damaged; 1 point – very high winter hardness, bushes were not damaged). Based on the fruit mass the yield of bushes per hectare was calculated.

Data were analysed by ANOVA table (one-way analysis). To evaluate significances of difference between variants, the least significant difference ($LSD_{0.05}$) was calculated; also the standard error was determined. Significant differences were marked by asterisks (*) in figures.

Results and Discussion

In Estonia there are undeveloped regions where the cultivation of non-traditional berries has started. Especially, the small farms are mainly located in areas, which are economically undeveloped. To build up those regions there is a need to support activities that would provide income (Fig.1). The figure also shows for example that the main blueberry production areas are situated in South-Estonia. At the moment there are many berry growers in Estonia and the production areas are constantly increasing. During recent years as compared with traditional berry crops there was an expansion of new berry cultures like blueberry and seabuckthorn (Fig.2).

In the production conditions in South Estonia the yield of lowbush blueberry 4 years old plants was 0.2 kg per bush; the calculated yield per hectare was 3.2 t. The average yield of 7 year old plants was 0.6 kg per bush and the yield per hectare was 9.6 t. The higher yield of 'Northblue' was obtained in a case where the mineral soil was mixed with peat and covered with peat or plastic mulch. The lowest yield was in a variant where no peat was added to the growth substrate and no mulch was used (Fig. 3).

Early results showed a positive response for plant growth and yield to mulching (Moore, 1993). Data from this experiment showed that the half-highbush blueberry grew best when peat was used (ground mixtures and peat mulch). The plastic mulch tended to improve growth. At the same time the sawdust mulch did not increase growth. The cultivar Northblue is considered to be a good half-highbush blueberry for commercial plantings because it has high yield potential (Luby et al., 1989). The cultivation of half-highbush blueberry will be a useful new line of berry production in Estonia.

The yield of blackberry cultivars was for 'Agawam' 2.7 kg per bush and 6.0 t ha^{-1}, for 'Black Satin' it was 2.6 kg per bush and 5.9 t ha^{-1}. The yield of Tayberry from a bush was 1.1 kg and 2.5 t ha^{-1}. The cultivar Agawam suffered less frost damage; higher frost damage was observed on 'Black Satin' (Fig. 4, 5). The estimated winter damage in 2002 of the experimental plants was between 2 and 8 points. Statistically there was more winter damage to the cultivar Black Satin. The Tayberry had average winter damage, 5 points. The study showed that the blackberry cultivar Agawam has good winter hardiness, but cultivar Black Satin is unsuitable for the Estonian climate: during the 2001/2002 winter all canes froze. In 2001/2002 the winter temperatures were low, an average temperature was -8°C (Agroclimatic data 2001, 2002) and there was not enough snow cover. This was a reason why most canes of 'Black Satin' were destroyed, but the root system was not harmed and in 2002 spring, plants formed new primocanes. One of the most difficult problems is winterhardiness for blackberry cultivar growers (Selonen, Tigerstedt, 1989). Blackberry canes are injured at temperature below -23°C (Moor, Skirvin, 1990). To resolve that problem interspecific hybrids between raspberries and blackberries could be used. Winter hardiness is very important for blueberry cultivation too, especially in North Europe (Haffner, Vesterheim, 1994; Paasisalo et al., 1994). The results from present experiment showed that the yield per bush of blackberry cultivar Agawam could be 2-5 kg. From cultivar Agawam the biggest yield of bush obtained was 1.67 kg and the average yield was 0.88 kg (Parksepp,

1977). Based on present experimental results, it is possible to say that the blackberry cultivar Agawam which forms thorns has high winter hardiness and high yield, for which reason it could be recommended for usage on local plantations. Blackberry cultivar Black Satin is thornless, is very cold-sensitive and is not suitable for cultivation in Estonian conditions. Although neither herbicides nor pesticides were used the blackberry cultivar Agawam yield was high. In lowbush blueberry plantation fertilizers were supplied in every third year. It shows that we are dealing with low demanding plant species.

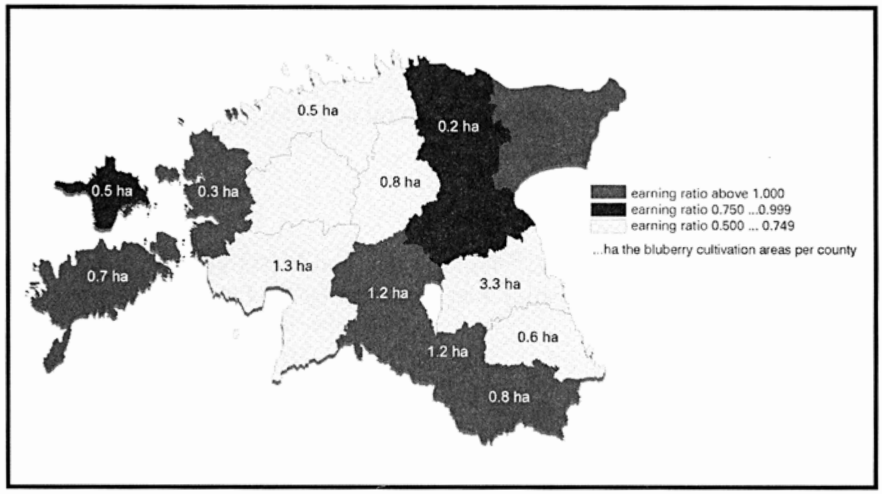


Fig. 1: The main blueberry cultivation areas in Estonia.

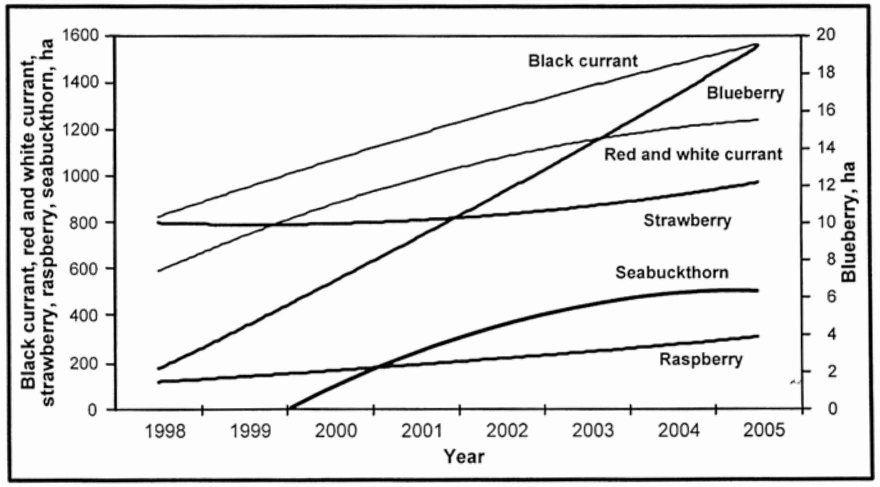


Fig. 2: The trends of berry production areas (ha) in Estonia (from 1998 to 2005).

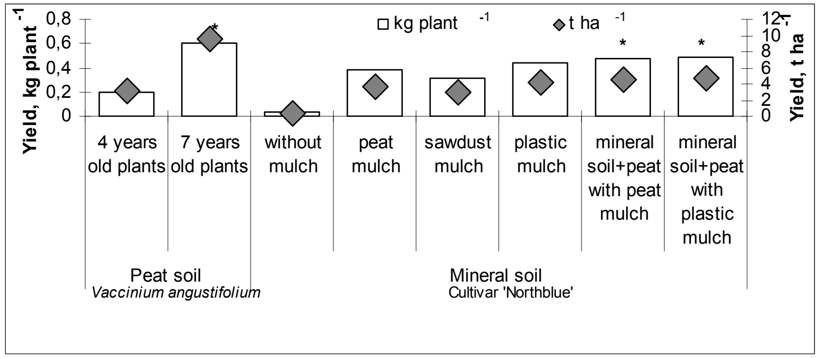
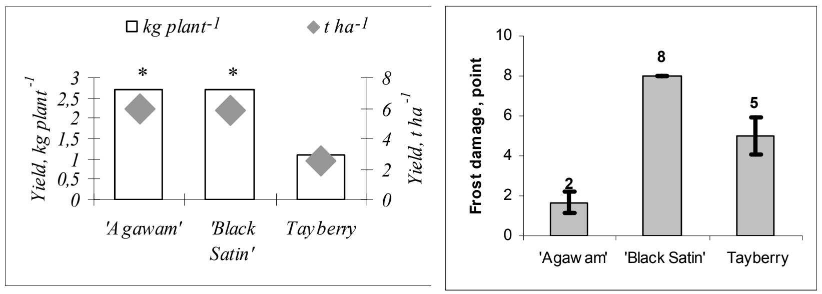


Fig. 3: The yield of lowbush blueberry and cultivar Northblue under different cultivation technologies in years 1998-2001.
*** Significant differences at P<0.05**



A **B**

Fig. 4: The yield (A) and frost damage (B) of some *Rubus* taxa in year 2002 (mean, STDEV). Frost damage (1 points - no frost damage, 9 points - all plant are damaged).
*** Significant differences at P<0.05**

Conclusions

During the last five years the berry cultivation areas have increased in Estonia and that trend will continue. In order to increase the selection of present berry cultures our research showed that the lowbush blueberry, half-high blueberry cultivar Northblue and blackberry cultivar Agawam are suitable. These berry cultures offer high yield, good winter hardiness and can be cultivated with methods of sustainable agriculture. Eventually it will facilitate the sustainable agricultural systems distribution, especially in the areas that are economically undeveloped. An exception is the blackberry cultivar Black Satin, which is very cold-sensitive and so not suitable for cultivation in Estonian conditions. Moreover, the above-mentioned species grow well on poor soils and on opencast peat pits that are not preferred for other agricultural activities.

Acknowledgements

We thank the small businesses Marjasoo talu and Metsa talu for their support during the experiment. This study was supported by the Estonian Science Foundation (Project 4726).

References

EPMÜ Eerika vaatlusjaama agrometeoroloogiline ülevaade. Koostanud M. Lang, 2001/1-12, 2002/1-10 (In Estonian).

Haffner, K., Vestrheim, S. 1994. Kulturheidelbeeren – Eine neue Beerenproduktion in Norwegen. Erwerbsobstbau, 36 (7): 184-187.

Luby, J.J., Wildung, D.K., Stushnoff, C., Mansion, S.T., Read, P.E., Hoover, E.E., 1989. 'Northblue', 'Northsky', and 'Northcountry' Blueberries. Horticultural, Science, 21 (5): 1240-1242.

Moore, N. 1993. Adapting Low Upland Mineral Soils for Culture of Highbush blueberries. Acta Horticulturae, 346: 221-229.

Moor, J.N., Skirvin, R.M. 1990. Blackberry management. In Small fruit crop management (eds. G.J. Galletta and D.G. Himelrick). Prentice Hall. New Jersey, p. 214-244.

Mücke, K.H., Rieger, U. 1968. Der Garten drinnen und draussen. – München, Südwestverlag, S. 436.

Paasisalo, S. 1997. Cultivated Blueberries New in Finland. International News Forum for Professional Berry Growers. 1: 8-9.

Parksepp, J. 1977. Vaarikad. – Tallinn, Valgus – 141 lk. (In Estonian).

Selonen, K.R.E., Tigerstedt, P.M.A. 1989. The use of interspecific crosses in breeding winterhardy blackberries in Finland. – V International Symposium on Rubus & Ribes, ISHS Acta Horticulturae, 262: 133-140.

Smolarz, K., Mercik, S. 1993. Growth and yielding of highbush blueberry (Vaccinium corymbosum L.) in response to long-term (since 1923) differential fertilization. Acta Horticulturae, 346: 193-198.

2001 Agricultural census. Statistical Office of Estonia. 2002.

II

Vool, E., Noormets, M., Karp, K., Mänd, R., Starast, M. 2003

POLLINATORS AND THEIR FORAGING BEHAVIOUR IN ARCTIC BRAMBLE (*RUBUS ARTICUS* L.) PLANTATIONS IN ESTONIA

Integrative approaches towards sustainability in the Baltic Sea Region, 15: 481-489

Pollinators and their Foraging Behaviour in Arctic Bramble (*Rubus Arcticus L.*) Plantations in Estonia

E. Vool[1], M. Noormets[1], K. Karp[1], M. Mänd[2], M. Starast[1,3]

[1]Institute of Horticulture
[2]Institute of Plant Protection
Estonian Agricultural University
Kreutzwaldi 64, Tartu 51014
Estonia

[3]University of Tartu, Institute of Botany and Ecology
Lai St. 40, Tartu 51005
Estonia

Summary

The movement patterns of the foraging behaviour of bees were observed in the EAU experimental garden in the second year after the planting of the arctic bramble, i.e. in the first harvest year. The track of a foraging honeybee on a row was followed from its arrival to departure. The length of the row covered during one flight was taken for the forage distance. Bees moved along a row choosing the nearest flowers irrespective of the cultivar. Fifty-eight per cent of the bees covered no more than one metre of the row (three plants) and 23% – up to two metres. Therefore, alternately planted cultivars are needed to increase berry production. Plastic mulch around the bramble planted in rows prevents the plants from spreading and reduces the danger of geitonogamy.

The arctic bramble is a self-incompatible and insect-pollinated plant, therefore its productivity largely depends on pollinators. That is why the arctic bramble is suitable for cultivation in regions where the equilibrium of nature is preserved and wild pollinators are found. Based on reasons mentioned above, there was a need for a survey of pollinators in Estonian conditions, as we have a lack of that kind of data. Moreover, the culture should grow in a clear natural environment if the intact natural population is preserved. One important question considered was whether our environment is the kind of environment where enough pollinators exist.

Introduction

The natural habitats of the European arctic bramble (*Rubus arcticus* L. ssp. *arcticus*) spread over Northern Eurasia. These berries famous for their special aroma and flavor are used for liqueur production in Finland. Mostly wild berries are picked; however, their yield varies from year to year. For this reason, arctic bramble cultivation in plantations has been started. Widespread cultivars 'Pima', Mespi' and the new ones 'Marika', 'Elpee' and 'Muuruska', are being cultivated (Pirinen et al., 1998). Yields of the arctic bramble are not high; however, the liqueur industry buys the berries at a high price.

The arctic bramble has been under protection in Estonia since 1958 (The Red Data ..., 1998). Its area of distribution has been diminishing constantly due to extensive amelioration activities. At present the preservation of the wild population of the arctic bramble is problematic, as its habitats have narrowed considerably.

The Department of Horticulture of the Estonian Agricultural University (EAU) started experiments on arctic bramble cultivation in 1995. The first studies have demonstrated that cultivation of the arctic bramble in Estonia is quite promising; however, more investigations must be carried out before the final recommendations can be presented to the prospective producers (Karp, Starast, 1998). In the wild the arctic bramble grows in semishade under trees and therefore blooms later than in plantations, when the danger of night frosts is over and there are more pollinators available.

The arctic bramble is a self-incompatible insect-pollinated plant, therefore its productivity largely depends on pollinators (Tammisto, Rautanen, 1970). Their pollinating efficiency is limited by the thermal constrains on flight activity, and each species has a microclimatic 'window' within which foraging flight can be sustained (Corbert et al., 1993). On the other hand, the qualitative pattern of bramble pollinators in a plantation depends on plant associations around it and on both the number of pollinator species inhabiting these associations and the number of individuals within each species (Kearns et al., 1998). However, there is little published information about the foraging behaviour of pollinators on the arctic bramble, although some data from Finland have been reported (Ryynänen, 1973, Kangasjärvi, Oksanen, 1989). In Central Finland the most frequent visitors to arctic bramble flowers included bumblebees (Bombus spp.) and honeybees (*Apis mellifera*) from among Hymenoptera, and hover flies (Syrphidae) and some other larger flies from among Diptera (Ryynänen, 1973). It is not known which insects would utilize the arctic bramble as a food plant in Estonia. For this reason we had to determine the economically important bramble pollinators and to study their behaviour in Estonia where the arctic bramble has not been cultivated before and there are no data on the set of effective pollinators of this plant.

This is why the arctic bramble is suitable for cultivation in regions where the equilibrium of nature is preserved and wild pollinators are found. Based on reasons mentioned above, there was a need for a survey of pollinators in Estonian conditions, as we have a lack of that kind of data. Moreover, the culture should grow in a clear natural environment if the intact natural population is preserved.

One important question considered was whether our environment is the kind of environment where enough pollinators exist.

Materials and Methods

The two different experimental plantations were located in the southern part of Estonia, Tartu County, both in production conditions. One trial plot was located in the experimental garden of Estonian Agricultural University (EAU).

The experimental cultivation sites were placed 20 km from each other, so it was unlikely that the same pollinators visited more than one experimental area. The first experimental plot (Vasula, planted in August 1996) was surrounded by the apple-trees and strawberry plantations of a horticultural firm, there were cherry and plum-tree orchards (60 ha altogether) not far away as well. No plant protection means were employed in the experimental plantation; however, disease and pest control procedures were carried out in the nearby productive plantations. The second experimental plot (Kambja, planted in June 1997) was located at a small farm growing strawberries (0.15 ha) and blackcurrants (1 ha). Woods and thickets surrounded the farm. The farmer had 5 hives of bees. No plant protection measures had been taken at the farm or in its surroundings. The plants were planted as in Vasula. The third plot was situated in the experimental garden of the EAU and surrounded by various cultures on little plots (apple-trees, currants, flowers).

The number of various pollinators and their taxonomic attribution were determined in plantations at Vasula and Kambja where rows around bramble plants were covered with plastic mulch. The distance between plants within the rows was 33 cm that between the rows – 1.20 m. Plants of the Finnish cultivar 'Pima' and the Estonian clone were planted alternately.

Pollinators were counted on 2 m (six replications) after recording the number of opened flowers. During the flowering period insects visiting the flowers within a 30 minute interval in the morning, at noon and in the afternoon were counted and their species determined. The number of flowers visited by a single pollinator was recorded as well. The relationship between the number of opened and visited flowers, and the number of bees and bumblebees were studies based on regression analysis.

The foraging behaviour of bees was observed in the experimental garden of the EAU in the second year after planting, i.e. in the first year of production. The planting distance in a row was 30 cm; the space between the rows 1 m apart was covered with peat mulch. There were 10-30 flowers on a plant during the observation period. The track of a bee on a row was followed from its arrival till the departure from the row. The length of the row covered during one flight was taken for the forage distance. On every harvest day the number of druplets on ripe fruits was determined.

Results and Discussion

The arctic bramble flowers are usually five-petalled with numerous stamens and styles, each of the latter attached to an ovary that will develop into the fleshy druplet after fertilization. After hibernation the plants start to grow with the arrival of the first warm days. In plantations covered with black plastic mulch the earth warmed up quickly, and plants renewed their growth during the first warm April days. The first flowers opened in the first half of May already; in the wild where the arctic bramble grows in semi shade in the grass under trees it starts to bloom at the end of May. Under favourable conditions flowering lasted the whole summer until September, with a maximum intensity (up to 120 flowers per m^2) in June. In warm and dry summers flowering ended in July (no irrigation was used). The cultivars studied differed significantly ($t = -7.01167$, $df = 22$, $P = 0.000$) in the number of flowers at the peak of flowering when 'Pima' had 27 ± 7 and the Estonian clone 40 ± 6 flowers on a plant (Fig. 1, A).

Observations made during the flowering period showed that flowers of the arctic bramble were visited mainly by honeybees (*A. mellifera*) which constituted 75% of the total number of pollinators. They visited the flowers continuously during the whole period of intensive flowering (Fig. 1, B). Honeybee density was closely dependent on flower density. The number of honeybees increased steadily to a maximum on 21 May, a little after maximum flower density. Hover flies (*Syrphidae*) constituted 18% of the visitors to the flowers. However, in view of their small body size they are less valuable pollinators. Anthers in arctic bramble flowers are strongly pressed against each other and warped downward towards the centre, therefore larger insects are more efficient pollinators.

Bumblebees (*Bombus* spp.) made up only 7% of flower visitors in the plantations in spite of the fact that in Estonian conditions there were no significant differences in the density of bumblebees in cultivated and natural habitats (Mänd et al., 2002). The *Bombus lapidarius* and *B. lucorum* were the major bumblebee species. Bumblebees visited the plantation at the beginning of May and in June, i.e. at the beginning and at the end of the flowering period of the arctic bramble, not at its peak flowering (Fig. 1,B). In May the flowers of the arctic bramble were visited by queens (who tasted 1 or 2 flowers, then flew to new ones a couple of rows further and left the plantation pretty soon). In June the flowers attracted bumblebee workers who were more assiduous than the earlier queens. The phenology of bumblebees and their cast representation on the arctic bramble was closely related to the seasonal cycles of colony growth. Overwintered queens were seen to forage on the plantation at the beginning of flowering in May, but not later when the arctic bramble was in peak flowering. Presumably queens had established colonies and reared workers by that time. Observations of bumblebee workers were confined to the end of June. Unfortunately, the emerging of the first workers (foragers) in colonies occurred during a rapid de-

cline in flowering intensity, at the end of flowering, and they could not contribute much in pollination.

The pattern of arctic bramble pollinator communities in Finland is close to our results – there, too, honeybees are the major pollinators of these flowers (Kangasjärvi, Oksanen, 1989). In Estonia plantations the arctic bramble started to flower in the first half of May already when the weather is chilly and windy. The low temperatures strongly affect the number of honeybees, but not bumblebees to the same extent. It is well known that bumblebees continue to work in the field under weather conditions that deter honeybees from foraging, and they work longer hours (Wratt, 1968, Corbet et al., 1993). However, bumblebees foraged more quickly in terms of flower visits per minute, carried more pollen on their bodies than bees, and also deposited more pollen on stigmas (Willmer et al., 1994). Thus, at the beginning of flowering in the low temperatures of early spring, bumblebees may be considered better bramble pollinators than honeybees. However, honeybees should be supplied if natural populations of bumblebees are low.

As the arctic bramble is a self-incompatible insect-pollinated plant, the experimenter has to consider the behaviour of pollinators when choosing the planting distance between cultivars. Honeybees were the major pollinators on our experimental plots, so we observed their behaviour in a young plantation. Bees moved along a row choosing the nearest flowers irrespective of the cultivar. 58% of the bees covered no more than 1 m of the row (3 plants) and 23% up to 2 m (Fig. 2). Therefore cultivars characterized by abundant flowering ought to be planted alternately with other cultivars, one plant of the first cultivar between every 1-2 plants of the other one. The behaviour of pollinators was studied in Finland in an older plantation where in all probability there were more flowers. Pollinators moved along the rows as in our experiments; 62% of the foraging flights were limited to just one plant, 34% were made between plants of the same row, and only 37% of the flights occurred between the rows (Kangasjärvi, Oksanen, 1989).

The behaviour of the pollinators is economical in preferring the individual area with the greatest number of flowers rich in nectar (Heinrich, 1979, Zimmerman, 1983). At the flowering intensity of our experiments, the number of bumblebees was affected by the number of flowers in the plantation ($r = 0.4$, $n = 33$, $P < 0.05$), while the number of honeybees remained unaffected ($r = 0.1$, $P > 0.05$) (Fig. 2). All bumblebees prefer flowers that offer abundant nectar, because they are large insects with a high energy requirement, both for flight and for the muscular effort (Heinrich, 1979). Bumblebees prefer blackcurrants and raspberries, plus all berries and fruit trees; they visit flowers of redcurrant and gooseberry less often (Mänd et al., 1996). Our experimental plots were located in different surroundings. At Vasula the plot was situated within a large production area where in May and

June other berries and fruit trees were also in bloom. At Kambja there were blackcurrants and strawberry competing with the brambles.

In the case of same other plants, for instance *Cynoglossum officinale*, it was established that the amount of pollinators did not depend on the number of flowers (Vrieling et al., 1999). A greater number of flowers may attract more pollinators; however, more flowering may lead to more frequent geitonogamy (pollination between flowers of the same plant or clone) which has a negative effect on the yield of berries in self-incompatible plants through inbreeding depression. The arctic bramble belongs to the incompatible group of plants; therefore it is not recommendable to grow it without plastic mulch: without mulching, plants cover the whole row densely, and the resulting increase in the number of flowers in a row favours geitonogamy and decreases the probability of cross-pollination.

The fruit of arctic bramble resembles raspberry in its general appearance and size; however, the mature fruit does not fall apart from the receptacle. An average arctic bramble fruit weighs 1 g and consists of 15-30 single drupes. This number may range from 2 to 55 depending on the pollination rate (Ryynänen, 1973). In the case of self-pollination, fertilization does not take place at all, or poor fruits are formed. In our young experimental plantation the harvesting season lasted two months, July and August. The fruits consisted of 19…37 single drupes each (Fig. 3). Their number was markedly more at the 3rd, 4th and 5th harvest when the fruits had been fertilized during the height of flowering. Formation of normal fruits is an evidence of sufficient pollination having occurred in our experimental plantations.

When looking for a proper site of a new plantation, one has to consider the distance from the nest the pollinators are able to cover. It depends on a number of factors including the weather, the foraging area and the state of the nest. As a rule, nesting areas are located in permanent associations around a plantation as well. Bumblebees make foraging flights ranging between 70 and 631 m from the nest; the average foraging distance of bumblebees depends on the distribution of plants in the plantation. In a case of uniform distribution the flight is relatively short, while it increases with an aggregated distribution (Cresswell, 2000). For the best use of the resources of wild pollinators it is advisable to plant the arctic bramble in the form of a narrow strip or a small plantation near permanent associations. At the same time it would be necessary to employ honeybee colonies even in the vicinity of biotopes rich in wild pollinators.

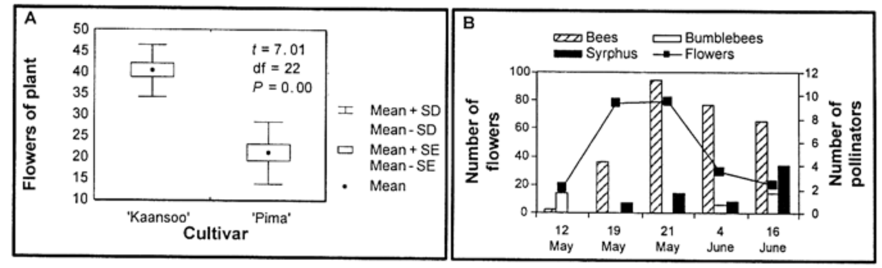


Fig. 1: The number of flowers per plant (A) and the number of pollinators and flower density at full blooming (B).

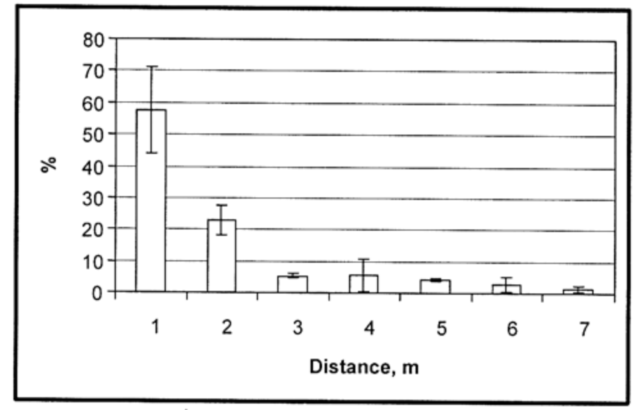


Fig. 2: Distribution (%) of honeybee foraging distances in arctic bramble plantation in the first year of production (mean, STDEV).

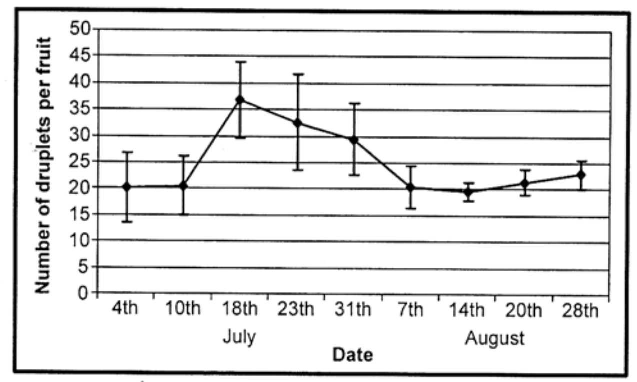


Fig. 3: The number of druplets per arctic bramble fruit on various harvest days (mean, STDEV).

Conclusions

On the basis of investigations under various production conditions carried out in South Estonia in 1996-1998, one may draw the following conclusions. In arctic bramble plantations honeybees are the major pollinators. The share of bumblebees and hover flies is much less. Bumblebees are more fastidious pollinators, and they prefer other wild forage plants when these are in bloom simultaneously. Honeybees make their foraging flights along the rows, and in a young plantation the foraging distance does not usually exceed 1 m. Our experiment showed that the environment in South Estonia has preserved its natural equilibrium, which is why there is no need for an additional supply of pollinators on plantations.

Acknowledgements

This work was supported by grants nos. 4726 and 4116 of the Estonian Science Foundation.

References

Corbet, S.A., Fussel, M., Ake, R. Fraser, A., Gunson, C., Savage, A., Smith, K. 1993. Temperature and the pollinating of social bees. Ecological Entomology, 18: 17-30.

Cresswell, E. 2000. A comparison of bumblebees' movements in uniform and aggregated distributions of theit forage plant. Ecological Entomology, 25: 19-25.

Kangasjärvi, J., Oksanen, J. 1989. Pollinator behaviour in cultivated and wild Arctic Bramble (Rubus arcticus L.). Journal of Agricultural Science in Finland, 61: 33-38.

Karp, K., Starast, M. 1998. Domestication of Estonian Arctic Bramble. Forestry Studies, No. 30, Tartu 1998: 70-75.

Karp, K., Starast, M., Tiido, T. 2000. Frost damages of Arctic Bramble (Rubus arcticus) and half-highbush blueberry (Vaccinium corymbosum x Vaccinium angustifolium) depend on cultivation methods. Proceedings of the International Conference: Fruit Production and Fruit Breeding. 244-247.

Krearns, C.A., Inouye, D.W., Waser, N.M., 1998. Endangered mutualisms: The Conservation of Plant-Pollinator Interactions. Annual Review of Ecology Systems., 29: 83-112.

Mänd, M., Bender, A., Kase, K., Martin, A.-J. 1997. Õietolmu koguvate mesilaselaadsete jaotumus konkureerivatel ristikuliikidel. Magistrantide ja doktorantide teaduslike tööde kogumik. Tartu, 193: 52-57 (In Estonian).

Mänd, M., Mänd, R., Williams, I.H. 2002. Bumblebees in the agricultural landscape of Estonia. Agriculture, Ecosystems and Environment, 89: 69-76.

Osborne, J.L., Clark, S.J., Morris, R.J., Williams, I.H., Riley, J.R., Smith, A.D., Reynolds, D.R., Edwards, A.S. 1999. A landscape-scale study of bumblebee foraging range and constancy, using harmonic radar. Journal of Applied Ecology, 36: 519-533.

Pirinen, H., Dalman, P., Kärenlampi, S., Tammisola, J., Kokko, H. 1998. Description of three new arctic bramble cultivars and proposal for cultivar identification. Agricultural and Food Science in Finland, 7 (4): 455-468.

Ruban, N., Kurlovich, T. 2000. Productivity of nectar of Oxycoccus macrocarpus. Problems of Rational Utilization and Reproduction of Berry Plants in Boreal Forests on the Eve of the XXI Century. Proceedings of the Conference 11-15 September 2000, Belarus. 210-213.

Ryynänen, A. 1973. Rubus arcticus L. and its cultivation. Ann. Agric. Fenn.,12: 1-76.

Teuber, L.R., Barnes, D.K. 1979. Environmental and genetic influences on quantity and quality of alfalfa nectar. Crop Science, 19: 874-878.

Vrieling, K., Saumitou-Laprade, P., Cuguen, J., Dijk, H., Joung, T.J., Klinkhamer, P.G.L. 1999. Direct and indirect estimates of the selfing rate in small and large individuals of the bumblebee pollinated Cynoglossum officinale L. (Boraginaceae). Ecology Letters, 2: 331-337.

Willmer, P.G., Bataw, A.M., Hughes, J.P. 1994. The superiority of bumblebees to honeybees as pollinators: insect visits to raspberry flowers. Ecological ntomology, 19: 271-284.

Wratt, E.C. 1968. The pollinating activities of bumblebees and honeybees in relation to temperature, competing forage plants, and competition from other foragers. Journal of Apicultural Research, 2 (7): 61-66.

Zimmerman, M. 1983. Plant reproduction and optimal foraging: environmental nectar manipulation in Delphinium nelsonii. Oikos, 41: 57-63.

III

Vool, E., Karp, K., Moor, U., Starast, M. 2007

YIELD QUALITY IN SOME TAXA OF THE GENUS *RUBUS* DEPENDING ON THE CULTIVATION TECHNOLOGY

European Journal of Horticultural Science, 72 (1): 32-38

Europ.J.Hort.Sci., **72** (1). S. 32–38, 2007, ISSN 1611-4426. © Verlag Eugen Ulmer KG, Stuttgart

Yield Quality in some Taxa of the Genus *Rubus* Depending on the Cultivation Technology

E. Vool[1)], K. Karp[1)], U. Moor[1)] and M. Starast[2)]
([1)]Estonian University of Life Science, Department of Horticulture, Tartu and [2)]University of Tartu, Institute of Botany and Ecology, Tartu, Estonia)

Summary

The purpose of this research project was to determine how mulching, specific harvesting times, and the differing weather conditions of the years involved affected the biochemical content of two *Rubus* family species: the raspberry (*Rubus idaeus* L.) 'Tomo' and the blackberry (*Rubus fruticosus* coll.) 'Agawam'. The appropriate data were recorded in the course of the years 2001–2004.

The 'Tomo' and 'Agawam' fruit weight was not significantly influenced by cultivation technology, but was influenced by harvesting time and the weather conditions of the particular year involved. The fruit dry matter (DM) was directly related to the berries' harvesting time. The soluble solids content (SSC) in the raspberry fruits was 9.9–13.3 % and 8.9–16.0 % in the blackberries. The raspberry fruits' SSC was significantly influenced by cultivation technology: the SSC was higher in berries grown without mulch. The ascorbic acid content (AAC) varied over the years, and depended mostly on the particular species. The raspberry fruits' AAC was significantly influenced by cultivation technology: the AAC was higher in berries grown without mulch. The blackberry fruits' AAC was also influenced by the harvesting time, being higher in berries from the last harvesting. The differing yearly wheather conditions had a greater effect on the blackberry fruits' titratable acids (TA) content.

The results indicated that fruit weight and biochemical content were primarily influenced by the differing weather conditions of the various years involved. The berries, for instance, contained more DM and soluble solids, and less TA in 2002. Cultivation technology had significant influence only on the raspberry fruits' AAC and SSC. Harvesting time had an impact on both the raspberry and the blackberry fruit weight and DM content, but the fruit SSC, AAC, and TA were affected only in the blackberry.

Key words. *Rubus idaeus* – 'Tomo' – *Rubus fruticosus* – 'Agawam' – polyethylene – fruit characteristics

Introduction

Both raspberry and blackberry are appreciated for their biochemical content, containing several valuable bioactive compounds beneficial for human health (Nikitina et al. 2000; Wang and Lin 2000). Blackberry, which is mostly cultivated in America, has not gain popularity in Europe because of its poor winter-hardiness and difficulties in fruit handling due to thorns on the stems. Raspberry, on the other hand, has longer cultivation history in Nordic countries, including Estonia. At the aim of minimizing production risks of berry farms, it is rational to diversify products. Blackberries have several benefits compared to raspberry, such as deep extending root system, which enables better survival in draught periods; ripe fruits better steadiness on stems; good pest resistance and transportation strength (Finn and Knight 2002). Moreover, blackberry has a late blooming time (June, July) and therefore spring frosts damage to generative organs is limited, which makes this berry suitable for cultivation in regions where late spring frosts occur. Spring frosts are recorded to occur in the middle of May until beginning of June in Estonia. Because of the late blooming time blackberry yield ripens late when compared to other berry crops, therefore it is easier to combine the cultivation of different berries on a farm. That would enable production and sales of different berry crops during longer period in Northland short vegetation conditions.

However, blackberry is not completely a new cultivated plant in Estonia. During 1954–1959 yield facts were collected and biochemical components of fruits were observed. Blackberry cultivar 'Agawam' was investigated as a new species in the Polli Horticultural Institute in Estonia in 1950 s. It was named as a very productive cultivar in Estonian conditions and was in a list of perspective cultivars in 1954–1962 (Parksepp 1977). Its natural representatives in Estonia are *R. nessensis* (W. Hall) and *R. caesius* (L.). The first has on erect and the latter has a semi erect growth habit.

The choice of berry cultivation technologies depends on regional conditions and production possibilities, and it can also be a tool for influencing biochemical content of berries. In strawberries it has been found that in the first cropping season plastic mulch reduces growth of weed seeds, but already in second cropping season strawberry yield decreases (Karp et al. 2002; Neuweiler et al.

2003). It is stated that using Black Mypex film reduces content of titratable acids in strawberries (NEUWEILER et al. 2003). In Estonian conditions it has been found that growing strawberries with plastic mulch and additional fertilization, content of vitamin C in strawberries increases (MOOR et al. 2004). NEUWEILER et al. (2003) mentioned that strawberries grown with coloured Mypex film and organic mulches are softer because of a looser cell structure caused by higher soil moisture under the mulch. PERCIVAL et al. (1998) described the positive influence of mulching on development of raspberry and blackberry plants root system. Also beneficial effect of plastic film on the raspberry vegetative growth and yield components have been noticed (PERCIVAL et al. 1998; LIBEK and KIKAS 2000). Since blackberries have deep root system compared to the raspberry, positive influence of mulching may be limited to only suppressing weeds in first growing years. Based on previously said, one can presume that with using different growing technologies and by that influencing the vegetative growth of *Rubus* species, we may also be able to influence biochemical content of berries; however this presumption needs to be ascertained by scientific experiments.

The aim of the present research was to find out the influence of mulching, harvesting time and experimental years with different weather conditions on raspberry and blackberry fruits' biochemical content.

Materials and Methods

Experimental site and plant material

The experiment was established in autumn 1999 in Estonian Agricultural University's experimental garden (58 º23 ' N, 26 º44 ' E), where plants reproduced from root suckers were used. Experiment data were collected from 2001 to 2004. The experiment consisted of four variants with three replications, at a plant density 1.5 × 2.5 m (plant × row spacing). Plants were set in rows oriented in North-South direction. Black Woven Ground Cover (100 g m^{-2}, UV, 100 % Polypropylene) was used as mulch. Mulch was placed on the bed and then plants were planted through the mulch. The soil in treatments without mulch was cultivated mechanically in accordance with requirement at the time of vegetation period.

Two different cultivation technologies were used: raspberry cultivar 'Tomo' without mulch; 'Tomo' with mulch; blackberry cultivar 'Agawam' without mulch; 'Agawam' with mulch. Raspberry cultivar 'Tomo' has been bred in Estonia and has good winter-hardiness and disease resistance. It is the most widely cultivated raspberry in Estonia (KIKAS et al. 2002). No irrigation system was used in the plantation. The yield of the raspberries was harvested 3–6 times depending on the year and usually harvest began at the middle of July (Table 1). The fruits of blackberries were harvested 5–7 times starting at the beginning or at the middle of August.

Table 1. The time and number of harvests on raspberry and blackberry in experimental years.

Species	Year	Harvesting time	Numbers of pick
Raspberry	2001	19 July–14 August	5
	2002	03 July–16 July	3
	2003	12 July–08 August	4
	2004	16 July–06 August	6
Blackberry	2001	08 August–05 October	7
	2002	05 August–12 September	5
	2003	13 August–03 October	6
	2004	19 August–19 October	7

Table 2. Weather conditions in 2001–2004 in experimental area as compared to the same figures of many years (1966–1998) in Estonia.

Year	Month						
	IV	V	VI	VII	VIII	IX	X
	Total precipitation (mm)						
2001	51.9	49	85.7	111.7	126.7	58.1	78.5
2002	20.1	15.4	80.7	44.7	22.2	20.5	41.3
2003	36.6	105	58.8	87.8	109.4	17.8	39
2004	6.0	37.8	184.0	76.2	104.8	86	35.4
1966–1998	35	55	66	72	79	66	56
	Average air temperature (Cº)						
2001	7.5	10.8	14.6	21.2	16.6	11.8	7.8
2002	12.2	19.8	16.5	25.4	25.5	14.9	4.0
2003	3.3	11.6	13.1	19.6	15.1	11.4	3.8
2004	5.1	9.5	12.8	16.0	16.4	11.8	5.7
1966–1998	4.3	11.6	15.1	16.7	15.6	10.4	5.5
	Total amount of radiation (MJ m^{-2})						
2001	141	250	229	292	211	117	47
2002	199	320	268	277	252	131	61
2003	162	223	234	250	188	136	51
2004	154	200	180	194	159	–	–

Table 3. Mean values of fruit weight in 2001–2004 depending on cultivation technology, time of harvest and experimental year.

Cultivar	Variant	$LSD_{0.05}$	2001	2002	2003	2004
			Fruit weight (g)			
Raspberry 'Tomo''	Effect of cultivation technology	0.4				
	without mulch		2.1bc	1.5d	2.4ab	1.9c
	with mulch		2.2bc	1.8cd	2.6a	1.8cd
	Effect of harvesting time	0.1				
	at the beginning of pick		2.3c	1.9d	2.3c	2.9a
	at the end of pick		1.9d	1.4e	2.7b	2.3c
	Average effect of year	0.3	2.1b	1.7c	2.5a	1.9bc
Blackberry 'Agawam'	Effect of cultivation technology	0.5				
	without mulch		2.1c	1.2d	2.7ab	2.8a
	with mulch		2.3bc	1.5d	2.8a	3.1a
	Effect of harvesting time	0.4				
	at the beginning of pick		3.0b	1.9c	1.8cd	3.6a
	at the end of pick		1.1e	1.0e	1.0e	1.5d
	Average effect of year	0.3	2.2b	1.4c	2.8a	3.0a

Soil

The soil was a stagnic luvisol, which texture is sand clay with humus layer 20–30 cm. Water regime in experimental area was moderately moist, with short term extensive moisture in spring after snow and in autumn after long lasting rainfall. The results of soil analyses (spring 2002) were as follows: P content: 141, K: 169, Mg: 64 and Ca: 1580 mg kg^{-1} (Mehlich method was used), organic matter – 2.6 % (Tjurini method was used), pH_{KCl} 5.1.

Weather

In review of EAU agrometeorology observatory was June 2004 and August 2001 the months with the most rainfall (Table 2). There was little rain in May 2002, in October 2002 and 2003 and in April 2004. As average of years are August with the most and April with little rainfall in Estonia. Among experimental years, 2002 was the year with highest temperatures in vegetation period; 2001 and 2003 had the most fluctuating temperatures. As average of years are July and August the months with highest temperatures in Estonia. Radiation activity was highest in 2002 and lowest in 2004.

Biochemical measurements

Chemical analyses were made once from frozen fruits every year in January. Dry matter (DM) was determined by drying fruits in thermostat (Memmet) to its stable weight (105 ºC). Soluble solids content (SSC) was determined in percentage with the refractometer (ATAGO Pocket Refract meter PAL-1, CO., Ltd., Japan). Ascorbic acid content (AAC) was determined with the modified Tillman's method, where 2 g of fruit material was first pounded and then 1 % HCl was added. Next it was filtered and measured in two replications (each 10 ml, 1 ml 1 % KJ and 1 ml 1 % soluble starch was added). Titratable acids (TA) content was found by weighing 5 g of material, which was pounded and then was 100 ml to 80 °C cooled water added. The mixture was heated for 30 min and set aside for 2 h. Next the mixture was filtered and measured in three replications 20 ml. Neutralizing method 0.1 N NaOH was used for titration. TA content was expressed as citric acid (mg in 100 g fresh fruits).

Statistical analysis

In order to study the influence of cultivation technology, time of harvest or year, data was analysed by one-way and two-way analysis variance. To evaluate significance of difference between variants, means were separated by the least significant difference ($LSD_{0.05}$).

Results

Cultivation technology did not influence raspberry fruit weight in any of the experimental years (Table 3). Harvesting time had significant influence on raspberry fruit

Table 4. Mean values of fruit dry matter and soluble solids content in 2001–2004 depending on cultivation technology, time of harvest and experimental year.

Cultivar	Variant	$LSD_{0.05}$	2001	2002	2003	2004
			Fruit dry matter (DM in %)			
Raspberry	Effect of cultivation technology	3.1				
'Tomo''	without mulch		17.7	17.3	19.0	16.9
	with mulch		16.6	17.4	17.7	16.2
	Effect of harvesting time	2.1				
	at the beginning of pick		17.6bc	16.2cd	17.0cd	16.5cd
	at the end of pick		15.3d	19.6ab	20.7a	17.0cd
	Average effect of year	2.2	17.1	17.3	18.4	16.6
Blackberry	Effect of cultivation technology	6.7				
'Agawam'	without mulch		17.7ab	20.6a	18.9ab	15.5ab
	with mulch		15.6ab	19.4ab	13.5b	15.3ab
	Effect of harvesting time	1.5				
	at the beginning of pick		19.2b	20.0b	19.2b	16.4c
	at the end of pick		16.4c	22.3a	17.0c	14.5d
	Average effect of year	4.7	16.7	20.0	16.2	15.4
			Soluble solids content (SSC in %)			
Raspberry	Effect of cultivation technology	0.7	13.0ab	13.3a	12.5bc	12.0cd
'Tomo''	without mulch		11.5d	13.2a	9.9e	11.7d
	with mulch					
	Effect of harvesting time	1.6				
	at the beginning of pick		12.4ab	12.5ab	11.3b	12.2ab
	at the end of pick		12.4ab	13.7a	11.3b	12.2ab
	Average effect of year	0.5	12.2b	13.3a	11.2c	11.8b
Blackberry	Effect of cultivation technology	1.2				
'Agawam'	without mulch		11.8b	16.0a	9.9c	9.6c
	with mulch		9.1c	15.2a	8.9c	9.1c
	Effect of harvesting time	1.6				
	at the beginning of pick		11.2c	15.1b	9.5d	12.4c
	at the end of pick		9.5d	16.8a	9.3d	9.5d
	Average effect of year	0.9	10.4b	15.6a	9.4c	9.4c

weight: fruits picked at the first part of the harvesting period were heavier. Only in 2003 fruits picked at the beginning of harvesting had smaller weight than those from later picks. Experimental year also had significant influence on fruit weight: the heaviest fruits were obtained in 2003. Blackberry fruit weight was also not influenced by cultivation technology in any of the experimental years. Similarly with raspberry, harvesting time had significant influence on fruit weight. Fruits picked at the beginning of the harvesting period were heavier throughout all experimental years. Experimental year also had significant influence on fruit weight: the heaviest fruits were obtained in 2004 and the lightest ones in 2002.

Raspberry fruit DM content was not influenced neither by cultivation technology either by experimental year (Table 4). Harvesting time had significant influence on fruit DM content, but the influence was yearly different: in 2002 and 2003 DM content was highest in last picked fruits, but in 2001 last picked fruits had the smallest DM content. Analogously with raspberry, blackberry

Table 5. Mean values of ascorbic acid content and titratable acids in 2001–2004 depending on cultivation technology, time of harvest and experimental year.

Cultivar	Variant	$LSD_{0.05}$	2001	2002	2003	2004
			Ascorbic acid content (AAC in mg 100^{-1}g fresh weight)			
Raspberry	Effect of cultivation technology	6.3				
'Tomo''	without mulch		23.3d	46.7a	38.4b	45.6a
	with mulch		25.6cd	29.1cd	31.7c	45.6a
	Effect of harvesting time	7.7				
	at the beginning of pick		23.5dc	38.1bc	37.3bc	54.2a
	at the end of pick		22.2d	42.3b	30.9c	40.7b
	Average effect of year	4.4	24.4c	37.9b	35.0b	45.6a
Blackberry	Effect of cultivation technology	3.4				
'Agawam'	without mulch		15.3ab	8.9cd	10.7c	16.4a
	with mulch		13.0bc	8.4cd	13.7bc	17.5a
	Effect of harvesting time	2.3				
	at the beginning of pick		15.2b	8.2e	13.0c	12.8c
	at the end of pick		15.3b	10.5d	12.8c	18.0a
	Average effect of year	2.4	14.1b	8.6c	12.2b	16.9a
			Titratable acids (TA in %)			
Raspberry	Effect of cultivation technology	0.4				
'Tomo''	without mulch		1.91ab	2.06a	1.88ab	1.50b
	with mulch		2.00a	1.75abc	1.77abc	1.47bc
	Effect of harvesting time	0.2				
	at the beginning of pick		1.78b	1.86b	1.80b	2.27a
	at the end of pick		1.97b	1.79b	1.83b	1.91b
	Average effect of year	0.3	1.95a	1.90a	1.83a	1.48b
Blackberry	Effect of cultivation technology	0.1				
'Agawam'	without mulch		0.50a	0.34c	0.48ab	0.40b
	with mulch		0.50a	0.34c	0.53a	0.42b
	Effect of harvesting time	0.1				
	at the beginning of pick		0.59b	0.44cd	0.47cd	0.43d
	at the end of pick		0.44cd	0.29e	0.54bc	0.72a
	Average effect of year	0.1	0.50a	0.34b	0.50a	0.41ab

fruit DM content was not influenced neither by cultivation technology either by experimental year. Harvesting time had significant influence: in 2001 DM content was highest in fruits from the latest pick, but in all other years it was highest in fruits obtained from first pick.

Raspberry fruit SSC was significantly different in variants with mulch and without it in 2001 and 2003: fruits from control variant had significantly higher SSC (Table 4). Harvesting time had no effect on raspberry fruit SSC. Experimental year influenced SSC, the highest SSC was found in 2002. Blackberry fruit SSC was significantly influenced by cultivation technology in 2001, when fruits from control variant had significantly higher SSC. Influence of harvesting time was yearly different: in 2002 fruits with highest SSC were obtained from first pick; in 2004 from last pick. Experimental year also influenced blackberry SSC: significantly higher SSC was found in 2002.

Raspberry fruit AAC was significantly different in variants with mulch and without it in 2002 and 2003, when fruits from variant without mulch had significantly higher AAC (Table 5). Harvesting time had an effect on AAC only in 2004, when fruits from first pick contained more ascorbic acid. Experimental year influenced raspberry AAC, which was significantly higher in 2004 and significantly lower in 2001. Blackberry fruit AAC was not influenced by cultivation technology. Harvesting time had an effect on AAC only in 2004, when contrarily to raspberry; fruits from last pick contained more ascorbic acid. Experimental year influenced blackberry AAC: significantly higher AAC was found in 2004 and significantly lower in 2002.

Raspberry fruit TA content was not influenced by cultivation technology (Table 5). Influence of harvesting time did not appear until the last experimental year, when TA content was higher in fruits from first pick. Experimental year influenced raspberry fruit TA content: in 2004 fruits contained less titratable acids. Blackberry fruits contained considerably less TA than raspberry fruits; cultivation technology had no effect on TA content. Influence of harvesting time on blackberry fruit TA was greater than in raspberry: in 2001 and 2002 fruits from first pick contained more and in 2004 less TA. Experimental year influenced blackberry fruit TA content only in 2002, when fruits TA content was significantly lower.

Discussion

Fruit weight

Significant influence of cultivation technology on fruit weight was not observed in present study; however, the tendency of mulch to increase fruit weight was noticed. It has been found in other studies, that plastic film increases raspberry fruit weight in first yield, but when the plantation ages, fruit weight decreases (Percival et al. 1998; Kikas et al. 2002). The reason, why effect of mulch did not appear in our experiment, could be related to soil characters in experimental area. Stagnic luvisol with sandy clay texture is known to have great water holding ability and therefore differences between growing conditions with and without mulch are smaller. Also pest damage was noticed, a redberry mite (*Acalitus essigi*) injuries being prevalent. Redberry mites cause uneven drupelets development and therefore influence fruit weight.

Harvesting time influenced fruit weight of both studied species. Fruit weight was always greater at the beginning of harvesting season. The exception was raspberry in 2003, when fruits from first pick were lighter than fruits from last pick. Mentioned exception could be caused by long and cool spring and little precipitation in June, when fruit ripening begins in Estonia. Thus we may say that one precondition for getting high yields in Estonian unstable weather condition is additional irrigation. Experiments in Latvia showed that by irrigation raspberry 'Polana' fruit weight increased up to 47,1 % (Buskiené and Petronis 2000). Another possibility could be floricanes shortening and tops cutting of primocanes in different height and time (Strick and Cahn 1999; Carew et al. 2000; Himelrick et al. 2000).

Dry matter

In present study fruit DM content was not influenced neither by experimental year or mulching. Average DM content in raspberry and blackberry was at the same level despite of different species. Raspberry DM content in present study was higher than previously recorded in Norway, where different raspberry cultivars had average DM content of 14.6 % (Haffner et al. 2002). DM accumulation and production in fruits is directly related to climatic conditions and especially with root-zone temperature (Boynton and Wilde 1959; Percival et al. 1998). Relation of DM accumulation with temperature was especially clearly noticed by 'Agawam' in summer 2002.

Influence of harvesting time on DM content appeared mostly in raspberry, where in 2002, 2003 and 2004 fruits from latest pick had higher DM content compared to the fruits from first pick. One influencing factor could be plant age, since *Rubus* plants have two - year's life cycle and after plants have had yield, water movement in plants is going to slow down.

Soluble solids

The present experiment showed that SSC in raspberry and blackberry fruits were affected by cultivation technology: SSC was higher in fruits from plants grown without mulch. Experiments with strawberries have also shown that ground cover did not increase SSC, even though sprinkling irrigation was used (Neuweiler et al. 2003). We may say that with cultivation technology we can also influence content of total sugars in raspberries and blackberries, because earlier experiments have shown that SSC in fruits is linearly related to the content of total sugars (Kallio et al. 2000; Gonzales et al. 2002).

Influence of harvesting time was only noticed on blackberries, where SSC was significantly higher in fruits from first pick. Mentioned finding could be related to fruit weight, which was also greater at the beginning of harvesting season. Similarly with the results of fruits DM content, the relation between SSC and experimental year through climate was noticed in our experiment. It has also been recorded about other berry cultures that SSC is affected by environmental conditions (Shaw 1990).

Ascorbic acid

Harvesting time had notable influence on AAC in both species, but whereas raspberry fruit contained more AAC at the beginning of pick, blackberry fruits were richer in AAC at the end of harvesting season. It has been found before that species and cultivar have an effect on AAC (deAncos et al. 1999). AAC content in our experiment depended significantly on year, which indicates that weather conditions influence AAC in berries. In Estonian conditions average AAC in raspberry fruits is recorded to be 31.6 mg and in blackberry fruits 38 mg (Parksepp 1977). Compared to mention findings, AAC content of fruits from both species was lower in our experiment, being 8.6–16.9 mg in blackberries 24.4–45.6 mg in raspberries. This can be explained by the fact that AAC in our experiment was determined from prior frozen fruits. Freezing experiments have shown that fruits preserve 78–88 % ascorbic acid compared to fresh fruits (Kampuse et al. 2002). Besides that, experiments with strawberries have shown that light intensity and temperature are the most important parameters in determining the final vitamin C content of the commodity and higher light intensities and cooler temperatures tend to increase the content of vitamin C (Lee and

Kader 2000). In present experiment opposite effect was noticed: during raspberry ripening in July radiation activity was highest in 2001 (292 MJ m^{-2}), at the same time lowest AAC content in raspberry fruits was determined. In 2004 radiation activity was the lowest (194 MJ m^{-2}) and AAC was the highest. The reason could be different growth habit of raspberries and blackberries compared to strawberry: plants are higher and fruits are situated between the leaves, being partially shadowed by them, which could decrease influence of radiation activity.

Titratable acidity

Raspberry fruits TA content in our study was 1.5–2.1 %, which is similar to results from the experiments carried out in Spain and Norway (1.7–2.3 %) (Gonzales et al. 2002; Haffner et al. 2002). Average TA content in blackberry fruits in the present study was 0.34–0.53 %. Cultivation technology had no influence on TA content in our experiment. The reasons for variations in TA are told to be cultivar characteristics and weather conditions (Haffner et al. 2002; Krüger et al. 2003). Harvesting time also had significant influence on TA content in blackberry fruits: in first two experimental years TA content was higher in first picked fruits and in 2003 and 2004 in last picked fruits. Experiments with strawberries have shown that TA content is higher with lower fruit set (Lenz and Buenemann 1967), which explains also our 2001 and 2002 years' results. Higher content of TA in 2003 and 2004 could be explained by plantation aging and also weather.

Conclusions

Based on research results, we may conclude that in raspberry and blackberry cultivation, using mulch in first yielding years enables to get larger fruits. Choosing right cultivation practise, it is possible to influence biochemical content, first of all SSC of raspberries and blackberries. We may suggest that fruits from plants grown without mulch contain more soluble solids, ascorbic acid and titratable acids. Harvesting time influences fruit weight and DM content of both species, but influence of harvesting time on fruit SSC, AAC and TA was greater on blackberry. Experimental year, meaning weather conditions also influences all biochemical components and fruit weight.

Growing new berry cultures in Northern countries, unstable weather conditions have to be taken into account, choosing right cultivation method in order to get fruits with optimum size, good taste and overall high quality.

References

Ancos, B. De, E. Gonzalez and M.P. Cano 1999: Differentiation of raspberry varieties according to anthocyanin composition. Eur. Food Res. Technol. **208**, 33–38.

Boynton, D. and H.M. Wilde 1959: Development of the black raspberry fruit. Seasonal increases in gross volume, dimension and dry weight. Proc. Amer. Soc. Hort. Sci. **73**, 158–163.

Buskiené, L. and P. Petronis 2000: Irrigation effect on growth and productivity of autumn raspberry cultivar 'Polana'. Fruit production and fruit breeding, Proc. Intern. Conf., EAU, 177–180.

Carew, G.J., T. Gillespie, J. White, H. Wainwright, R. Brennan and N.H. Battey 2000: Techniques for manipulation of the annual growth cycle in raspberry. J. Hort. Sci. Biotechnol. **75**, 504–509.

Finn, C. and H.V. Knight 2002: What's going on in the world of *Rubus* breeding? Acta Hortic. **585**, 31–35.

Gonzales, M.E., B. De Ancos and M.P. Cano 2002: Preservation of raspberry fruits by freezing: physical, physico-chemical and sensory aspects. Eur. Food Res. Technol. **215**, 497–503.

Haffner, K., H.J. Rosenfeld, G. Skrede and L. Wang 2002: Quality of red raspberry *Rubus idaeus* L. cultivars after storage in controlled and normal atmospheres. Postharvest Biol. and Technol. **24**, 279–289.

Himelrick, D.G., C.R. Ebel, M.F. Woods, S.B. Wikins and A.J. Pitts 2000: Effect of primocane topping height and lateral length on yield of 'Navaho' blackberry. Small Fruits Review **1**, 95–101.

Kallio, H., M. Hakala, A.M. Pelkkikangas and A. Lapveteläinen 2000: Sugars and acids of strawberry varieties. Eur. Food Res. Technol. **212**, 81–85.

Kampuse, S., K. Kampuss and L. Pizika 2002: Stability of anthocyanins and ascorbic acid in raspberry and blackcurrant cultivars during frozen storage. Acta Hortic. **585**, 507–510.

Karp, K., M. Starast and H. Kaldmäe 2002: Influence of the age of plants and foliar fertilization on the yield of strawberry cultivar 'Jonsok' under plastic mulch. Acta Hortic. **567**: 459–462.

Kikas, A., A. Libek and L. Hanni 2002: Evaluation of raspberry cultivars in Estona. Acta Hortic. **585**, 203–207.

Krüger, E., E. Schöpplein, S. Rasim, G. Cocca and H. Fischer 2003: Effects of ripening stage and storage time on quality parameters of red raspberry fruit. Europ. J. Hort. Sci. **68**, 176–182.

Lee, S.K. and A.A. Kader 2000: Preharvest and postharvest factors influencing vitamin C content of horticultural crops. Postharv. Biol. and Technol. **20**, 207–220.

Lenz, F. and G. Buenemann 1967: Beziehung zwischen dem vegetativen und reproduktiven Wachstum in Erdbeeren (var. 'Senga Sengana'). Gartenbauwissenschaft **32**, 227–236.

Libek, A. and A. Kikas 2000: First year vegetative growth of raspberry as a response to different types of mulching. Fruit production and fruit breeding, Proc. Intern. Conf., EAU, 181–184.

Moor, U., K. Karp and P. Põldma 2004: Effect of mulching and fertilization on the quality of strawberries. Agric. and Food Sci. **13**: 256–267.

Neuweiler, R., L. Bertschinger, P. Stamp and B. Feil 2003: The impact of ground cover management on soil nitrogen levels, parameters of vegetative crop development, yield and fruit quality of strawberries. Europ. J. Hort. Sci. **68**, 183–191.

Nikitina, V.S, G.V. Shendel, A.Y. Gerchikova and N.B. Efimenko 2000: Flavonoids from raspberry and blackberry leaves and their antioxidant activities. Pharm. Chem. J. **34**, 596–598.

Parksepp, J. 1977: Vaarikad. Valgus, Tallinn, 141 lk. (In Estonian).

Percival, C.D., J.T.A. Proctor and J.A. Sullivan 1998: Supplementary irrigation and mulch benefit the establishment of 'Heritage' primocane-fruiting raspberry. J. Amer. Soc. Hort. Sci. **123**, 518–523.

Shaw, D. 1990: Response to selection and associated changes in genetic variance for soluble solids and titratable acids content in strawberries. J. Amer. Soc. Hort. Sci. **115**, 839–843.

Strick, C.B. and H.K. Cahn 1999: Pruning and training affect yield but not machine harvest efficiency of 'Meeker' red raspberry. HortSci. **3**, 611–614.

Wang, S.Y. and H.S. Lin 2000: Antioxidant activity in fruits and leaves of blackberry, raspberry and strawberry varies with cultivar and development stage. J. Agric. Food Chem. **48**, 140–146.

Received April 29, 2005 / Accepted September 09, 2006

Addresses of authors: Ele Vool, Kadri Karp and Ulvi Moor, Estonian Agricultural University, Institute of Horticulture, Kreutzwaldi 64, Tartu 51014, and Marge Starast, University of Tartu, Institute of Botany and Ecology, Lai St. 40, Tartu 51005, Estonia, e-mail: ele.vool@emu.ee.

IV

Vool, **E**., Noormets, M., Karp, K., Moor, U., Starast, M.

THE PRODUCTIVITY AND FRUIT QUALITY OF THE ARCTIC BRAMBLE (*RUBUS ARCTICUS* SSP. *ARCTICUS*) AND HYBRID ARCTIC BRAMBLE (*RUBUS ARCTICUS* SSP. *ARCTICUS* X *RUBUS ARCTICUS* SSP. *STELLATUS*)

Acta Agriculturae Scandinavica, Section B- Soil and Plant Science (in press)

Acta Agriculturae Scandinavica Section B – Soil and Plant Science
2008, 1–8, iFirst article

Taylor & Francis
Taylor & Francis Group

ORIGINAL ARTICLE

The productivity and fruit quality of the arctic bramble (*Rubus arcticus* ssp. *Arcticus*) and hybrid arctic bramble (*Rubus arcticus* ssp. *arcticus* ×*Rubus arcticus* ssp. *stellatus*)

ELE VOOL[1], KADRI KARP[1], MERRIT NOORMETS[2], ULVI MOOR[1] & MARGE STARAST[1,3]

[1]*Estonian University of Life Sciences, Department of Horticulture, Kreutzwaldi 1, Tartu, 51014 Estonia,* [2]*Estonian University of Life Sciences, Department of Soil Science and Agrochemistry, Kreutzwaldi 1, Tartu, 51014 Estonia, and* [3]*University of Tartu, Institute of Botany and Ecology, Lai St. 40, Tartu, 51005 Estonia*

Abstract
The fruit biochemical content and productivity of arctic bramble (*Rubus arcticus* ssp. *arcticus*) and hybrid arctic bramble (*R. arcticus* ssp. *arcticus* × *R. arcticus* ssp. *stellatus*) cultivars were investigated during three experimental years (2001–2003) in field conditions. Rows of experimental plants were alternated with rows of raspberry (*Rubus idaeus* L.). Finnish cultivars together with a strain from Estonian nature (E1) and Finnish and Swedish hybrid cultivars were planted in rows that were covered with plastic mulch. The cultivars and strain were planted in rows turning in order to secure the best conditions for pollination. The following combinations were used: E1 + 'Susanna'; E1 + 'Mespi'; E1 + 'Pima'; 'Astra' + 'Aura'; 'Astra' + 'Anna'; 'Anna' + 'Beata'. Yield and biochemical content were different between variants consisting of two cultivars. Significantly higher yield parameters such as fruit weight, number of drupelets, and productivity were observed from the hybrid cultivars 'Astra' + 'Aura'. Combinations with arctic bramble cultivars did not have a significant difference in yield, thus all tested cultivars are suitable for growing in combination with Estonian clone. Hybrid arctic bramble fruits in cultivar combinations of 'Astra' + 'Anna' showed the highest titratable acid (TA) content. E1 and 'Susanna', in combinations with arctic bramble, had higher soluble solids and ascorbic acid content, but TA and SS/TA did not show significant differences. The darkest (L*) and reddest (+a*) juice was found in fruit of hybrid cultivars combinations; those combinations with 'Astra' produced the darker juice colouring.

Keywords: *Ascorbic acid, chromaticity, drupelets, fruit weight, soluble solids, titratable acid, yield.*

Introduction

Arctic bramble (*R. arcticus* ssp. *arcticus*) is found in subarctic Eurasia, mainly between the latitudes of 60° N and 70° N. The growing areas are located in a broader zone in Asia as well as in northern parts of North America, ie. Canada and Alaska. The best Eurasian habitats are located between 62° and 66° latitude (Ryynänen, 1973). Estonia is situated on the southern boundary of the arctic bramble's area of distribution, where the bramble is naturally adapted to growth in the half-shadow of forest undergrowth (Reier, 1982). Another subspecies, *R. arcticus* ssp. *stellatus,* has a narrow distribution range in NW Alaska, the Aleutian Islands, and in NE Asia. The subspecies *stellatus* and *arcticus* can be crossed and vigorous hybrids obtained (Larsson, 1969, 1980; Ryynänen, 1973). In 1999, in Finland, the arctic bramble plantations areas covered 20–25 ha, in Sweden 10–15 ha (Anon., 1999).

The first arctic bramble experiments were carried out in Finland at the beginning of the 1970s (Ryynänen, 1973). The first Swedish hybrid cultivars (*R. arcticus* ssp. *arcticus* × *R. arcticus* ssp. *stellatus*) were released in 1980 (Larsson, 1980). In Estonia, the experimental work with arctic bramble began in 1994. The main problem of arctic bramble cultivation in Estonia and Finland is infection with downy mildew (*Peronospora sparsa*). The infection is mainly favoured by low temperature and water deficiency stress in the plant. The second major

Correspondence: E. Vool, Estonian University of Life Sciences, Department of Horticulture, Kreutzwaldi 1, Tartu, 51014 Estonia. E-mail: ele.vool@emu.ee

(Received 16 October 2007; accepted 4 February 2008)

ISSN 0906-4710 print/ISSN 1651-1913 online © 2008 Taylor & Francis
DOI: 10.1080/09064710802022903

problem, dependent on the prevailing environmental conditions, is the rapid growth of young shoots in the beginning of the spring. The arctic bramble rhizome buds that are located near the soil level begin early growth during the favourable conditions in spring. The young shoots can therefore be damaged by late spring night frost (Tammisalo, 1988; Karp et al., 2000). A third problem in Estonia is too high temperatures in plantations in summer. Partial shading is, therefore, recommended to suppress rapid growth of arctic bramble in early spring and to reduce temperature in summer. Experiments in Finland have been carried out where spruce hedges provide partial shading (Prokkola et al., 2001). An alternative is to cultivate the arctic bramble with other species, for example, raspberries. The first advantage of using raspberries is the uniform height and width of the plants during the vegetation period and consequently uniform shading conditions are achieved during the whole summer. The second is that the raspberry plants give wind protection for the arctic bramble plants, providing the windless conditions favourable for pollinators, especially bees.

Arctic bramble cultivars are self-sterile and, for ensuring yield, different arctic bramble strains should be cultivated together (Hiirsalmi, 1975; Kangasjärvi & Oksanen, 1989). When arctic bramble cultivars are planted alternately in rows and the plant-to-plant spacing is 0.33 m, plants will be grown in combination as a mixture of cultivars by the second year, because arctic bramble rhizomes can grow 0.5 m or more in one year (Ryynänen, 1973). The distance between different arctic bramble cultivars in a row should not exceed 1 m as honeybees make foraging flights along the rows, and this distance is the length of a bee's foraging flight (Vool et al., 2003).

The earliest arctic bramble cultivars are 'Mespi' and 'Pima' (strains of *R. arcticus*), which are recommended for cultivation (Ryynänen, 1972). The most well known and widely distributed cultivars of arctic bramble hybrids in Finland are 'Aura' and 'Astra', of which 'Astra' has been recommended as a pollinator for 'Aura' (Hiirsalmi et al., 1987). Under Estonian conditions, experimentation has shown that cultivars' yield and pollen potential is different each year (Karp & Starast, 1999). A combination of three cultivars was the subject of an Estonian experiment in an attempt to ensure better pollination and increasing yield, but no advantages were found in comparison with the two-cultivars combinations (Karp et al., 2000).

The advantage of the Estonian arctic bramble strain compared with the Finnish cultivars is its significantly vigorous vegetative growth and productivity (Karp & Starast, 1998, 1999); furthermore the Estonian strain grown under Finnish conditions and compared with the Finnish arctic bramble showed good infection resistance (Prokkola et al., 2001). Swedish hybrid cultivars, compared with the arctic bramble cultivars, are thought to be more opulent and productive, but have a weaker aroma (Larsson, 1980); however, they are more resistant to downy mildew fungus (Hellqvist, 2000). Therefore more hybrid cultivars need to be studied under Estonian conditions, since to date experiments only with Finnish cultivars have been conducted.

Arctic bramble fruits are mainly used as raw material in the food and liqueur industry, therefore the biochemical properties of these fruits are of major importance. In Estonia and Finland the fruits of hybrid cultivars contain more acids than do the arctic bramble fruits (Häkkinen et al., 1994; Starast et al., 2000). 'Aura' and 'Astra' among the hybrid cultivars have the lowest sugar content and are less aromatic, but Starast et al. (2000) found that 'Astra' fruits had a significantly redder colour. It is important to note that the fruits of arctic bramble and hybrid cultivars have different biochemical content (Karp, 2001). Since for successful pollination a mixture of different cultivars is grown in the plantations, the food industry gets a mixture of fruit from several cultivars.

The primary aim of the present research was to determine suitable Finnish arctic bramble cultivars for cultivation in combination with the Estonian strain. The secondary aim was to find out the effect of cultivar combinations on yield, biochemical content, and yield colour when analysed as a mixture of two cultivars.

Materials and methods

Experimental site and soil conditions

The arctic bramble field experiment was established in Tartumaa (58° 15′N, 26° 38′E), in South Estonia on luvisol (IUSS Working GroupWRB, 2006). The soil of the experimental area contained 82 mg P l^{-1}, 267 mg K l^{-1}, 150 mg Mg l^{-1}, 0.79 mg B l^{-1}, 1100 mg Ca l^{-1}, and 2.8 mg Cu l^{-1}. The soil pH_{KCl} was 5.6.

Rows of arctic brambles were grown alternately with raspberries (*R. idaeus* L.). The raspberries were planted in 1999 and the arctic bramble plants in May 2000. The experimental plants were planted on a bed with plastic mulch (black polyethylene with a thickness of 0.06 mm) with width of 60 cm. The plastic mulch was laid out before planting, the holes in the plastic being cut larger every year. A drip-irrigation system was placed under the mulch. The distance between plants in the rows was 33 cm.

The area between the plastic mulch rows of arctic bramble and raspberry plants was covered with sawdust mulch.

Plant material

The arctic bramble has been a protected species in Estonia since 1958. E1 is the first cultivated Estonian arctic bramble ssp. *arcticus* strain originating from Nature. In 1995 the strain was removed, with permission from the Estonian Environment Ministry, from its habitat in Kaansoo for experiments. 'Mespi', 'Pima'. and 'Susanna' are Finnish arctic bramble ssp. *arcticus* cultivars. The hybrid arctic bramble (*Rubus arcticus ssp. stellatus*) cultivars 'Aura' and 'Astra' are from Finland and 'Anna' and 'Beata' from Sweden. There were 72 plants in variant (24 plants in three replications). Because of the self-sterility of arctic brambles, every variant consisted of 2 cultivars (12 + 12 plants in replication), which were planted in rows alternately. The following cultivar combinations were used: E1 + 'Susanna'; E1 + 'Mespi'; E1 + 'Pima'; A'stra' + 'Aura'; 'Astra' + 'Anna'; 'Anna' + 'Beata'.

Measurements

Yield. In the first crop year (2001) the yield was harvested seven times, and three times in 2002 and in 2003. The experiment was carried out until 2005, but in 2004 and 2005 no considerable yield was formed and therefore these years were not included in the current work. The yield was expressed in units of g m^{-2}. Average fruit weight and the number of drupelets per fruit were determined during the harvest. The number of shoots per bush was counted and their length measured (cm) at the same time. The length of shoots was measured from the ground to the shoot tip. The leaf area (mm^2) was also measured (ADC BioScientific Ltd. Area meter AM100).

Biochemical analyses of fruits. Biochemical analyses of the frozen berries of arctic brambles were conducted in January 2002 and 2003. Soluble solids (SS) content was determined as a percentage using a refractometer (ATAGO Pocket Refractometer PAL-1). Titratable acid (TA) content was measured by the titration method with aqueous 0.1 N NaOH, using phenolphthalein as an endpoint indicator. 5 g of material was weighed, ground, and then water at 80 °C was added. The mixture was heated for 30 minutes and set aside for 2 hours. Next the mixture was filtered and three replications of 20 ml each were measured off. The TA content was expressed as citric acid mg per 100 g of fresh fruits. The soluble solids and titratable acids (SS:TA) ratio was calculated based on the content of soluble solids and TA. Ascorbic acid content (AA) was determined with the modified Tillman's method, where 2 g of fruit material was first ground and then 1% HCl was added. Next the mixture was filtered and the filtrate was measured in two 10 ml replications (1 ml of 1% aqueous KI and 1 ml of 1% soluble starch were added).

Colour. The colour of the filtered and heated 5% berry juice was determined. The fruit juice colour was measured using a MINOLTA Chroma meter CR-400. The index numbers used were lightness (L^*) and the chromaticity coordinates. The letter a^* indicates colour directions: $+a^*$ is the red direction, $-a^*$ is the green direction.

Meteorological conditions of experimental years

All three experimental years had different climatic conditions. Precipitation during 2001 was significantly higher than the long-term average (1960–1999) (Table I). Abundant precipitation also occurred in May, July, and August 2003. 2002 was significantly warmer and dryer than the long-term average. The warmest month during the experimental years was July. In 2001, the warmest months, when compared with the long-term average, were April and July.

Statistical analysis

The average results of the three years (2001–2003) were used to study the influence of cultivars and strain combination on the arctic bramble fruit biochemical composition and yield. A two-way analysis of variance (ANOVA) was used for data analysis; the factors were A – cultivars combination, and B – years. The mean values to be compared are followed by the same letter if they are not significantly different at $P < 0.05$. Linear correlation coefficients between variables were calculated; the significance of coefficients being $P < 0.05^*$, $P < 0.01^{**}$.

Results

Yield

The fruit weight ranged from 0.6 to 1.2 g, depending on the cultivars combination (Figure 1A). The fruit size was not dependent on the year, but the cultivars' properties had a significant effect. All hybrid

Table I. Meteorological conditions of experimental years in 2001–2003 and long-term averages 1960–1999.

	Temperature (°C)				Precipitations (mm)			
Month	2001	2002	2003	Long-term averages	2001	2002	2003	Long-term averages
April	7.5	6.5	3.3	4.3	52	20	37	35
May	10.8	13.9	11.6	11.0	49	15	105	55
June	14.6	16.5	13.1	15.1	86	81	59	66
July	21.3	21.1	19.6	16.7	112	45	88	72
August	16.6	19.2	15.1	15.2	127	22	109	79

cultivars had heavier fruits than did arctic bramble cultivars. Lighter fruits were found in arctic bramble combinations E1 + 'Pima', heavier fruits in hybrid cultivar combinations 'Astra' + 'Aura' and 'Anna' + 'Beata'.

The number of drupelets differed between variants, from 10 to 26 per fruit (Figure 1B). The hybrids 'Astra' and 'Aura' had the highest number of drupelets. When compared with the arctic bramble cultivars the hybrids had a higher number of drupelets. E1 and 'Susanna' fruit mix had the lowest number of drupelets. In 2001, there were significantly more drupelets compared with other years.

The duration of the harvest period varied during the experimental years. The fruiting period of the arctic bramble was 26 June to 7 August in 2001, 22 June to 8 July in 2002, and 27 June to 11 July in 2003. In all three experimental years the main yield ripened at the end of June to the beginning of July. In 2004, the yield was harvested only twice and in 2005 a considerable yield was not obtained. The productivity of experimental plants was highly variable – the yield ranged from 17 to 91 g m^{-2} (Figure 1C). There were no significant differences between arctic bramble variants. The hybrid cultivars 'Astra' and 'Aura' had significantly higher productivity than did other cultivars. In 2003, the productivity was significantly lower than in the rest of the experimental years.

Correlation analysis showed a positive relationship between yield and fruit weight ($r = 0.82^{**}$), yield and drupelets number ($r = 0.76^{**}$), also between the fruit weight and drupelets number ($r = 0.74^{**}$). Similarly, a positive correlation was found between drupelets number and shoot number ($r = 0.60^{*}$). The size of leaves did not influence the productivity.

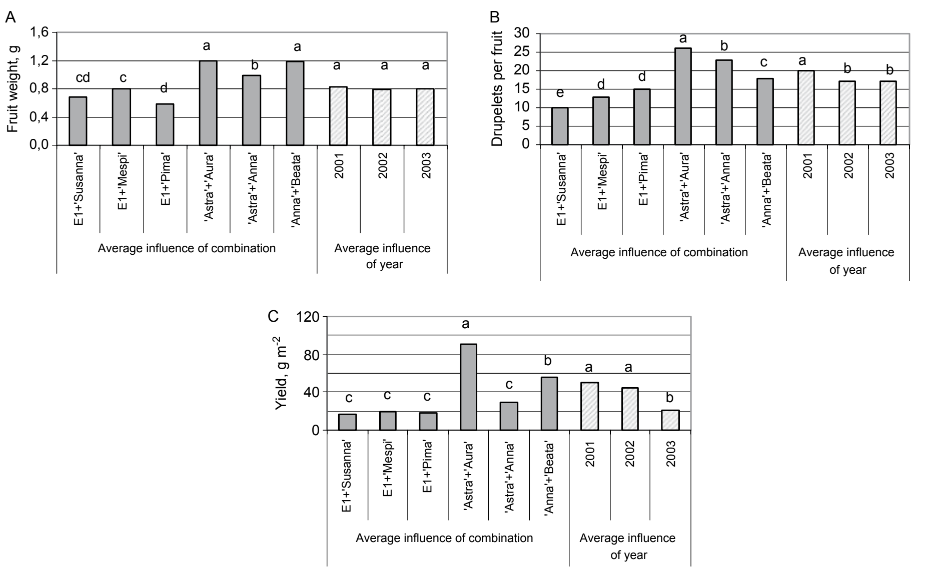


Figure 1. The influence of cultivar and strain combinations on the arctic bramble. A- fruit weight (g), B- number of drupelets (per fruit), and C-yield (g/m^{-2}) as an average of three experimental years (2001–2003).

E. Vool et al.

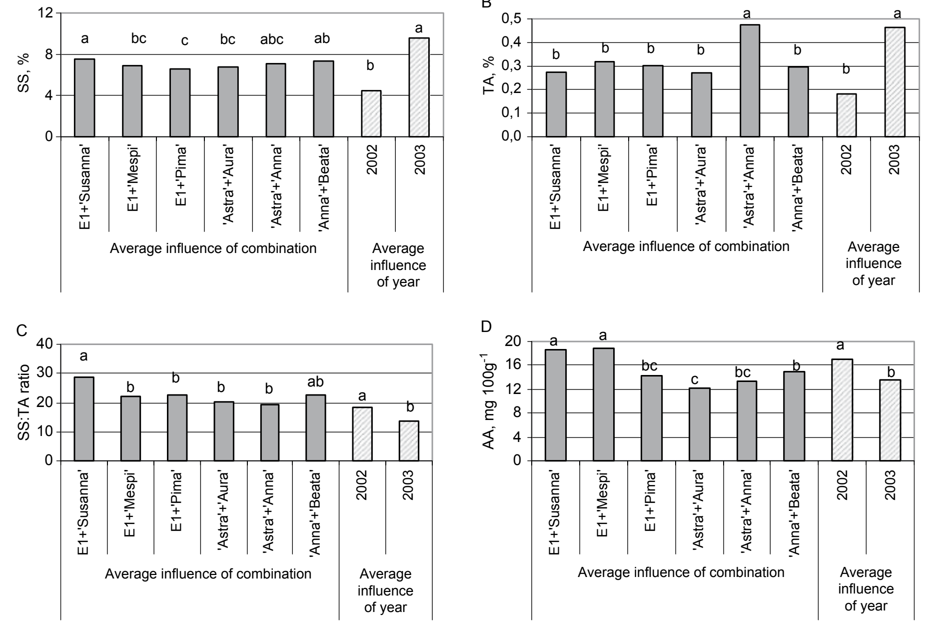


Figure 2. The influence of cultivar and strain combinations on the arctic bramble fruit biochemical composition over two experimental years (2002–2003). A – Soluble solids (%), B – titratable acids (%), C – ratio of soluble solids and titratable acids, D – ascorbic acid (mg per 100 g).

Biochemical indicators

SS content of the fruit was 6.6–7.5% and was significantly dependent on the cultivars and year: E1 + 'Pima' had significantly less SS than did E1 + 'Susanna' (Figure 2A). There were no differences between SS content of hybrid cultivars. In 2002, the fruits contained less SS than in other years.

The TA content of the fruits ranged from 0.27 to 0.48% during the experimental years (Figure 2B). The 'Astra' + 'Anna' fruit mix contained more acids, but there was no significant difference between other cultivars. The TA content was lowest in 2002.

The SS:TA ratio was influenced by cultivars. The ratio was significantly higher in strain E1 and 'Susanna' when compared with the hybrid cultivar combinations containing cultivar 'Astra' (Figure 2C). Comparing experimental years, in 2002 the fruits had a significantly higher SS:TA ratio than in the second year.

The AA content of arctic bramble ranged from 12 to 19 mg (100 g)$^{-1}$ (Figure 2D). E1 combinations with 'Susanna' and 'Mespi' had significantly higher AA content than did other combinations. Correlation analysis showed a negative correlation between fruit weight and AA ($r = -0.67^{**}$), shoot number and AA ($r = -0.65^{*}$), and between the TA and shoot length ($r = -0.58^{*}$).

Colour

The cultivars' properties influenced the juice colour. Significantly higher L^* values of fruit juice were found in the E1 combination with 'Mespi' or 'Pima' (Figure 3A). Significantly lower $+a^*$ values were found in E1 and 'Pima' mixes (Figure 3B). Darker juice was obtained from hybrid cultivar combinations where 'Astra' was used. The correlation between drupelets number and L^* ($r = -0.56^{**}$) was negative. A positive correlation was found between the drupelets number and a^* values ($r = 0.55^{**}$), also between AA content and L^* ($r = 0.57^{**}$). A positive correlation was found between the leaf area and a^* values ($r = 0.56^{*}$), but there was a negative correlation between the shoot number and L^* ($r = -0.57^{*}$).

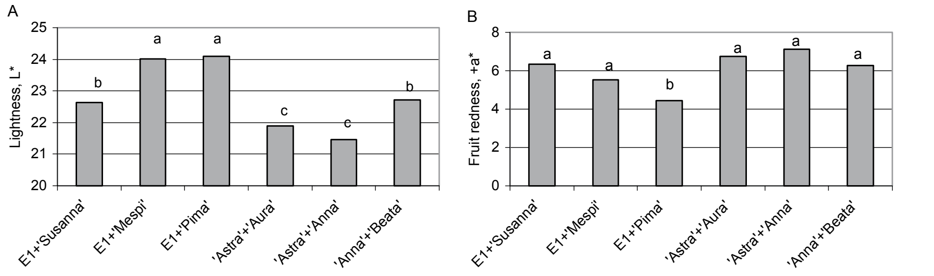


Figure 3. The influence of cultivar and strain combinations on the arctic bramble. A – Fruit lightness (L*), B – fruit redness (+a*) in 2003.

Discussion

Yield parameters

Arctic bramble fruits contained 10–15 drupelets, but hybrid fruits had 17–27 drupelets and that was dependent on the year. Better results (averaging 20 drupelets) were obtained in 2001. In arctic brambles, which are insect-pollinated, drupelets number depends on pollination success (Kangasjärvi & Oksanen, 1989). The data of Reier (1982) showed that well pollinated flowers would develop fruits with 15–30 drupelets. Thus, the conclusion can be made that pollination in the current experiment was not very successful and that hybrid cultivars were better pollinated. In addition to cultivars' characteristics, pollination success and the presence of pollinators is greatly dependent on yearly climatic conditions. The reason for the greater number of drupelets in 2001 was possibly due to a larger amount of precipitation in summer that increased the moisture content in air (Table I). Air moisture is an important factor for the pollen-grain development inside a flower. In the third year diseases negatively influenced the drupelets number.

The yields of arctic bramble were shown to be significantly lower than those of the hybrid cultivars. In the current experiment, the highest yield of the three experimental years was in arctic bramble hybrid cultivar combinations 'Astra'+'Aura' and 'Anna'+'Beata'. 'Aura' has also shown high productivity in Finnish experiments and has been recommended for growing in combination with 'Astra' (Hiirsalmi et al., 1987). At the same time the current experiment indicated that 'Astra' is not the best combination for 'Anna', because the yield was lower than in the combination 'Anna'+'Beata'. In Finnish experiments 'Anna' has been one of the most productive cultivars among Swedish hybrids (Prokkola et al., 2001). Based on our results, the conclusion can be made that hybrid cultivars originating from the same country are more suitable for growing together. In arctic bramble variants, E1 was used in combination with Finnish cultivars. Although the number of drupelets and fruit weight differed between variants, there were no significant differences in yield. Cultivar 'Susanna' had not been used in experiments in Estonia before, but based on the current research results 'Susanna' can give the same amount of yield as 'Pima' and 'Mespi'. Thus, if we want to choose a pollinator for the Estonian local clone, none of the Finnish cultivars from the current experiment can be preferred based on yield.

Biochemical indicators

The averages of the three experimental years showed that the SS content in arctic bramble fruits varies, even if the fruits are picked from a two-cultivar mixture. The highest SS content was found from fruits in combinations E1+'Susanna' compared with E1+'Pima'. No significant differences in SS content were found comparing arctic bramble cultivars with hybrid cultivars. These results are different from those of previous experiments, where lower SS content occurred in fruits of hybrid cultivars (Häkkinen et al., 1994), with significant differences between the cultivars (Karp, 2001). Previous experiments showed that a lower SS content is found in fruits of 'Aura' and 'Astra'; the average SS content in fruits was 3.8–6.1% (Häkkinen et al., 1994; Starast et al., 2000). In the current experiments it was around 7%. The significant effect here could be the habitat as well as microclimatic conditions. In other words, the arctic bramble plants were surrounded with raspberries and they offer partial shadow, moreover they reduced the temperature fluctuations during the fruit-ripening period.

The TA content was high in fruits of 'Astra' and 'Anna, whereas Hiirsalmi et al. (1987) recorded that 'Astra' had more acidic fruit. TA content in other hybrid variants was similar to that of arctic bramble cultivars. Previously conducted experiments have shown that hybrid cultivars produce more acidic fruits (Häkkinen et al., 1994; Starast et al., 2000;

Karp, 2001). The average TA content in fruits in the current experiment was 0.33%, which is relatively low yet similar to results presented from Finland, showing citric acid content to be 0.3–1.9% (Häkkinen et al., 1994). In addition to partial shadow, the results were influenced by plant growth. Plant height has a considerable effect on TA content. The highest TA content was found in fruits of plants with a lower, shrub-type growth. The proposition could be that the effect on results obtained here is due to different light conditions. Based on the SS:TA ratio the sweetest fruits in the current experiment were in variants E1+'Susanna' compared with the hybrid cultivar combinations containing 'Astra'. The important indicator here is the consumers' sense of taste; the higher the SS:TA ratio the sweeter the taste, while the lower the ratio the sourer the taste of the fruits (Haffner et al., 2002).

In the current experiment a higher AA content was found in Estonian strain fruits with 'Susanna' and 'Mespi'. The average AA content in arctic bramble fruits over the experimental years was 16 mg (100 g)$^{-1}$. This is lower than that found in previous experiments conducted in Estonia, which showed AA content to be 19–25 mg (100 g)$^{-1}$ (Starast et al., 2000). Differences could be caused by partial shading by raspberries or by different annual climatic conditions. Since July was the warmest month during all three experimental years it could have caused the decrease of AA in fruits (Table I). The AA content in the current experiment was also dependent on the fruit weight and the shoot number; the AA content was higher in the case of lower fruit weight and shoots number.

The presence of an intense red colour is important in arctic bramble, which is a valuable raw material resource for liqueur production. In the current experiment cultivars' properties had a significant effect on juice colour. The darker juice was produced from combinations 'Astra' with 'Anna' or 'Aura'. The current results showed that cultivar 'Astra' improves the colour of cultivars mixture fruits. 'Astra' has also had good colour in previous experiments in Estonia (Starast et al., 2000). Among arctic bramble cultivar combinations with the Estonian clone, the juice was darker when 'Susanna' was used in combination. Thus 'Susanna' had the best colour among Finnish cultivars. In the current experiment erratic fruit colouring influenced the arctic bramble fruit juice colour. Most of the fruit was dark red and soft, but 1–3 drupelets remained yellow. Pirinen et al. (1998) also noticed this kind of erratic colouring. In the current experiment, however, the erratic fruit colouring did not occur on hybrid cultivars. Moreover, correlation analysis showed that arctic bramble drupelets number significantly influenced the colour; the more drupelets present, the darker and redder the fruit.

The experimental result showed that average yield of arctic brambles in different years is the same. Biochemical content of fruits from two-cultivar combinations is different in most characteristics.

Content of TA was similar in combinations, but SS content and SS:TA ratio were higher in combination where the Estonian clone was grown together with 'Susanna'; this combination also produced the darkest juice. Therefore the Estonian clone+'Susanna' combination can be recommended.

Hybrid cultivar combinations showed that cultivars originating from the same country should be grown together for ensuring higher yields – good combinations were 'Astra'+'Aura' and 'Anna'+'Beata'. The biochemical content of a mixture of two hybrid cultivars was different only in TA and AA content. The colour of the mixture was improved when 'Astra' was used.

It is important to continue the research in order to examine disease resistance of cultivars, since in the current experiment yield could only be harvested during the first three years. After these three years the plants were infected and no significant yield was obtained.

Acknowledgements

This research was financially supported by Estonian Science Foundation (grant No 4726).

References

Anon. (1999). Mesimarjan ja jalomaaraimen viljely. *Kvarkenrådet*, Vasa (in Swedish and Finnish), 48S.

Haffner, K., Rosenfeld, H., Skrede, G., & Wang, L. (2002). Quality of red raspberry (*Rubus idaeus* L.) cultivars after storage in controlled and normal atmospheres. *Postharvest Biology and Technology*, *24*, 279–289.

Hellqvist, S. (2000). Establishment of Hybrid Arctic Bramble under Field Conditions. *Acta Agriculturae Scandinavica*, *50*, 169–177.

Hiirsalmi, H. (1975). Berry fruit characteristics in cultural studies. *Liitteesta, Koetominta ja Kaytanta*. Nr.1:4.

Hiirsalmi, H., Junnila, S., & Säkö, J. (1987). Mesimarjan jalostus johtanut tulokseen. *Maatalouden Tutkimuskeskus*, *18*, 9–21 (in Finnish).

Häkkinen, S., Kokko, H., & Kärenlampi, S. (1994). Sugar and organic acid in clones and cultivars of arctic bramble and hybrid, sensory evaluation of juices and jellies. *Agricultural Science in Finland*, *4*, 385–395.

IUSS Working GroupWRB (2006). Word reference base for soil resources 2006. 2nd edn. *WordSoil Resourses Reports*. No. 103. FAO, Rome. 145 pp.

Kangasjärvi, J., & Oksanen, J. (1989). Pollinator behaviour in cultivated and wild Arctic Bramble (*Rubus arcticus* L.). *Journal of Agricultural Science in Finland*, *61*, 33–38.
Karp, K. (2001). Effect of growing technology and cultivar on growth and yield of arctic bramble (*Rubus arcticus*) and strawberry (*Fragaria x ananassa*). Thesis for the award of a doctor's degree in agricultural sciences in plant production. Tartu University, 136 pp. (in Estonian).
Karp, K. & Starast, M. (1998). Domestication of Estonian natural arctic bramble. *Forestry Studies* XXX, Wild Berry Culture: an Exchange of Western and Eastern Experiences, 70–75.
Karp, K., & Starast, M. (1999). The suitability of Estonian natural arctic bramble (*Rubus arcticus* L.) for field cultivation. *Transactions of the Estonian Agricultural University*, *Agronomy*, *203*, 33–35 (in Estonian).
Karp, K., Starast, M., & Reier, Ü. (2000). Factors affecting the yield of arctic bramble (*Rubus arcticus* L.) cultivated in Estonia. In: Proceedings of the international Conference: *Problems of rational utilization and reproduction of berry plants in boreal forests on the eve of the XXI century.* pp. 158–160.
Larsson, G. (1969). Experimental taxonomy as a base for breeding in Northern *Rubi*. *Hereditas*, *63*, 283–351.
Larsson, G. (1980). *Rubus arcticus* L. subsp. × *stellarcticus*, a new arctic raspberry. *Acta Horticulturae*, *112*, 143–144.
Pirinen, H., Dalman, P., Kärenlampi, S., Tammisalo, J., & Kokko, H. (1998). Description of three new arctic bramble cultivars and proposal for cultivars identification. *Agricultural and Food Science in Finland*, *7*, 455–468.
Prokkola, S., Valkonen, J., Koponen, H., & Luoma, S. (2001). Lehtihomeenkestävien mesimarjakantojen valinta. *Pohjoisen Laatumarjat – mansikka, tyrni, mesimarja ja jalomaarain.* MTT, Maa-ja elintarviketalouden tutkimuskeskus, Pohjois-Pohjanmaan tutkimusas-ema, Pohjorden laatumarjat-hank ISBN 951-729-617-7 83–88 (in Finnish).
Reier, Ü. 1982. *Murakad.* Valgus, Tallinn. 159 pp. (In Estonian).
Ryynänen, A. (1972). Arctic bramble (*Rubus arcticus* L.) a new cultivated plant. *Annales Agriculturae Fenniae*, *11*, 170–173.
Ryynänen, A. (1973). *Rubus arcticus* L. and its cultivation. *Annales Agriculturae Fenniae*, *12*, 1–76.
Starast, M., Karp, K., & Pae, A. (2000). Organic acid, ascorbic acid and sugar content of arctic bramble depending on variety ant its cultivation place. *Journal of Agricultural Science*, *XI*(1) 81–87 (in Estonian).
Tammisalo, J. (1988). Incompatibility classes and fruit set in natural populations of arctic bramble (*Rubus arcticus* L.) in Finland. *Journal of Agricultural Science in Finland*, *60*, 327–446.
Vool, E., Noormets, M., Karp, K., Mänd, R., & Starast, M. (2003). Pollinators and their foraging behaviour in arctic bramble (*Rubus articus* L.) plantations in Estonia. Integrative approaches towards sustainability in the Baltic Sea Region, *Enviromental Education, Communication and Sustainability*, *15*, 481–489.

CURRICULUM VITAE

First name Ele

Surname Vool

Date of birth 26.09.1975

Institution Estonian University of Life Sciences,
Institute of Agricultural and Environmental Sciences,
Department of Horticulture

Childern Madleen Vool (17.01.2008)
Mattias Vool (27.05.2005)
Martin Vool (23.09.1998)

Education 2003-2009 Estonian University of Life Sciences,
doctoral studies
2001-2003 Estonian Agricultural University,
master studies
1997-2001 Estonian Agricultural University,
undergraduate
1982-1993 Secondary School Alatskivi

Foreign languages
German, English, Russian

Research and professional experience
2004-... Estonian University of Life Sciences,
Dep. Of Horticulture, assistant
2004-2008 Estonian Agricultural University,
Dep. of Horticulture, senior laboratorian
2002-2004 Estonian Agricultural University,
Dep. Of Horticulture, laboratorian

Academic degree
2003 Master's degree (M.Sc) of Agricultural Science:
"The yield and the quality of berries of different
genus Rubus taxa"

Training activities
2007 Germany, Hochschule Neubrandenburg
„Seminar zur Land- und Ernährungswirtschaft"
2003 Denmark, The Royal Veterinary and Agricultural
University; scholarship
2003 Sweden, Falkenberg; Values, Ideology, Science,
and Organic Farming; NOVA Ph.D course

Main fields of research
Biosciences and environment, agricultural sciences
(cultivation and quality of wild berries cultivation
of berries)

Grant funding and projects
2005-2008 Estonian Science Fondation (ESF)
grant 6046,
Influence of different cultivation methods on the
productivity, crop quality and on the cultivation
evironment. Breeding of the blueberry and
lingonberry varieties
2004-2008 TF project 0172655s04, Development of
environmentally friendly plant protection II
2006 Enterprise Estonia (EAS) project 8-2/
T6075PKPK06, Blueberries as raw material for
functional food
2001-2006 EAS project 8-2/T017AGAI01,
Cultivation technologies and selection of lowbush
blueberry, http://www.eau.ee/~agt/mustikas/index.html
2000-2004 ESF grant 4726, New berries culture
(*Rubus arcticus, Vaccinium angustifolium, Vaccinium
corymbosum* x *V. angustifolium, Vaccinium vitis-idaea*)
cultivation and selection

Honours and awards
2003 Estonian Ministry of Education and Research.
Governmental competition for researchworks;
Diploma for Master thesis "The yield and the quality
of berries of different genus *Rubus* taxa"

ELULOOKIRJELDUS

Eesnimi Ele

Perekonnanimi
Vool

Sünniaeg 26.09.1975

Töökoht Eesti Maaülikool,
Põllumajandus- ja keskkonnainstituut,
aianduse osakond

Lapsed Madleen Vool (17.01.2008)
Mattias Vool (27.05.2005)
Martin Vool (23.09.1998)

Haridus
2003 EPMÜ põllum. tead. magistrikraad aianduse erialal
2001 EPMÜ bakalaureuse kraad aianduse erialal
1997 Tartu Meditsiinikool, meditsiiniõde
1993 J. Liivi nim. Alatskivi Keskkool

Võõrkeelteoskus
Saksa, inglise, vene

Teenistuskäik
2004 september-… EMÜ, aianduse osakond, assistent
2004-2008 EPMÜ, aianduse instituut, vanemlaborant
2002-2004 EPMÜ, aianduse instituut, laborant

Teaduskraad
2003 magistrikraad taimekasvatuse erialal: "Perekonna *Rubus* erinevate taksonite saagikus ja viljade kvaliteet"

Erialane enesetäiedus
2007 Saksamaa, Hochschule Neubrandenburg „Seminar zur Land- und Ernährungswirtschaft"
2003 Taani, The Royal Veterinary and Agricultural University
2003 Rootsi, Falkenberg; Values, Ideology, Science, and Organic Farming, NOVA Ph.D kursus

Teadustöö põhisuunad
Bio- ja keskkonnateadused, põllumajandusteadus (metsamarjade kultuuris kasvatamine, marjakultuuride agrotehnika, sordid, kvaliteet)

Osalemine uurimisprojektides
2005-2008 ETF grant 6046, Erinevate kultiveerimisviiside mõju metsamarjade produktiivsusele, saagi kvaliteedile ja keskkonnale
Mustika- ja pohlasortide aretus, põhitäitja
2004-2008 SF0172655s04, Keskkonnasäästliku taimekaitse-tehnoloogia arendamine II, projekt täitja
2006 EAS 8-2/T6075PKPK06, Kultuurmustikad spetsiaaltoodete toorainena, põhitäitja
2001-2006 EAS 8-2/T017AGAI01, Ahtalehise mustika kasvatus-tehnoloogiad ja sordiaretus, põhitäitja, http://www.eau.ee/~agt/mustikas/index.html
2000-2004 ETF grant 4726, Uute marja-kultuuride (*Rubus arcticus, Vaccinium angustifolium, Vaccinium corymbosum* x *V. angustifolium, Vaccinium vitis-idaea*) kultiveerimine ja selektsioon, doktorant

Tunnustused
2003 Eesti Haridusministeeriumi Riiklikult teadustööde konkursilt diplom magistritööle "Perekonna *Rubus* erinevate taksonite saagikus ja -viljade kvaliteet"

LIST OF PUBLICATIONS

1.1

Moor, U., Põldma, P., Tõnutare, T., Karp, K., Starast, M., **Vool, E**. 2009. Effect of phosphite fertilization on growth, yield and fruit composition of strawberries. Scientia Horticulturae, 119: 264-269.

Vool, **E**., Noormets, M., Karp, K., Moor, U., Starast, M. The Productivity and Fruit Quality of the Arctic Bramble (*Rubus arcticus* ssp. *arcticus*) and Hybrid Arctic Bramble (*Rubus arcticus* ssp. *arcticus* x *Rubus arcticus* ssp. *stellatus*). Acta Agriculturae Scandinavica, Section B- Soil and Plant Science (in press).

Vool, E., Karp, K., Moor, U., Starast, M. 2007. Yield quality in some taxa of the genus *Rubus* depending on the cultivation technology. European Journal of Horticultural Science, 72 (1): 32-38.

Starast, M., Karp, K., **Vool**, **E**., Paal, T. Albert, T. 2007. Effect of NPK fertilization and elemental sulphur on growth and yield of lowbush blueberry. Agricultural and Food Science, 1: 34 - 45.

1.2

Starast, M., Karp, K., **Vool**, **E**., Moor, U., Tõnutare, T., Paal, T. 2007. Chemical Composition and Quality of Cultivated and Natural Blueberry Fruit in Estonia. Vegetable Crops Research Bulletin, 66: 143 - 153.

1.3

Starast, M., Karp, K., **Vool**, **E**., Moor, U. 2005. The cultivation of half-high bush blueberry under organic farming condition. Egyptian Journal of Agricultural Research, 83: 155 – 168.

3.1

Starast, M., Kõljalg, U., Karp, K., **Vool**, **E**., Noormets, M., Paal, T. 2006. Mycorrhizal colonization of half-high blueberry cultivars influenced by cultural practices. Acta Horticulturae 715: 449-454.

Noormets, M., **Vool, E.**, Karp, K., Värnik, R., Starast, M. 2003. New trends in development of Estonian berry production towards to sustainable agriculture. Integrative approaches towards sustainability in the Baltic Sea Region, 15: 467-473.

Vool, E., Noormets, M., Karp, K., Mänd, R., Starast, M. 2003. Pollinators and their foraging behaviours in arctic bramble (*Rubus articus* L.) plantations in Estonia. Integrative approaches towards sustainability in the Baltic Sea Region, 15: 481-489.

3.2

Starast, M., Karp, K., Moor, U., **Vool**, **E**., Paal, T. 2003. Effect of fertilization on soil pH and growth of lowbush blueberry (*Vaccinium angustifolium* Ait.) – 14th International Symposium of Fertilizers, “Fertilizers in context with resource management in agriculture”. Debrecen, Hungary. Proceedings of the Conference, II: 628-635.

3.4

Starast, M., Paal, T., **Vool**, **E**., Karp, K., Noormets, M. 2005. Effect of hexazinone in young low-bush blueberry plantation. Scientific international conference Kultura brusnitshnik jagodnikov: itogi i perspektivy. Minsk: Smeltok: 85 - 89.

3.5

Starast, M., **Vool**, **E**., Karp, K. 2004. Pamplisordi ‘Agawam’ ja läänevaarikasordi ‘Jewel’ produktiivsus. Agronoomia, 219: 103 - 105.

Starast, M., Karp, K., **Vool**, **E**., Paal, T., Moor, U. 2005. Kärpimise mõju ahtalehise mustika seemikute kasvule. Agronoomia, 220: 111 - 113.

Vool, **E**. 2002. Mõnede *Rubus* perekonna taksonite viljade biokeemiline koostis. Säästev põllumajandus Eestis- kogemused, võimalused, suundumused, CD-Rom.

6.4

Starast, M., Karp, K., Paal, T., Värnik, R., **Vool**, **E**. 2005. Kultuurmustikas ja selle kasvatamine Eestis. Tartu: Eesti Põllumajandusülikool, 65 lk.

Eskla, V., Libek, A., Hanni, L., **Vool**, **E**., Niiberg, T. 2003. Vaarikas aias ja köögis. Tallinn: Maalehe Raamat, 183 lk.