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THE BENEFITS OF *Vaccinium* SPECIES IN ECOLOGICAL PRODUCTION

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ABSTRACT

More and more people are buying foods labeled as 'natural' or 'ecological'. It is much easier to cultivate *Vaccinium* species according to ecological rules than most fruit species. Growing cranberries and highbush and lowbush blueberries is an interesting way to diversify agriculture and improve the profitability of small family farms. The ecological benefits of *Vaccinium* species are reviewed and discussed.

Key words: *Vaccinium*, environment, mycorrhiza, mulching, fertilization, plant protection, ecological production

INTRODUCTION

Vaccinium species are an important fruit crop in many countries all over the world (Frith and Clayton-Greene, 1993; Moore, 1993; Munoz-Schick and Clayton-Greene, 1993; Tamada and Clayton-Greene, 1993). Blueberry and cranberry production have increased in recent years (Trinka et al., 1997; Caruso et al., 1997). In the USA, there are also some wild *Vaccinium* species (*V. angustifolium* Ait., *V. ashei* Reade, *V. macrocarpon* Ait.) which have been grown commercially after improvements in field management (Yarborough and Smagula, 1997).

In Poland and Eastern Europe, native wild species, such as *V. myrtillus* L., *V. vitis-idaea* L., *V. uliginosum* L., and *V. oxycoccus*, have not yet been exploited as commercial crops (Pliszka and Clayton-Greene, 1993), though blueberries (*V. corymbosum* L.) have been commercially grown since the 1970's. Cranberries (*V. macrocarpon* Ait.) are also now grown, but not as widely as highbush blueberries are.

Fruits of *Vaccinium* species contain abundant anti-oxidants, which function by neutralizing oxygen free radicals (Heimhuber and Herrmann, 1990). They are widely considered to be one of the healthiest foods available (Mainland and Tucker, 2002), and are a excellent source of fiber, calcium, iron, vitamin C, total phenolics, and anthocyanins (Ehlenfeldt and Prior, 2000). The antioxidant activity of blueberries depends on genotype, environment (Connor et al., 2002), and horticultural traits, such as yield and fruit size (Vorsa et al., 2002).

1. Environmental factors

Vaccinium species need special climate and soil conditions for optimal growth and productivity (Coville, 1910; Eck, 1988). They need about 160 days for vegetative growth, followed by a period of low temperatures (Hafner, 1993).

In northern climates, *Vaccinium* cultivars which are cold tolerant and bear no later than 'Bluecrop' are most suitable for profitable production (Hiirsalmi, 1993; Vestrheim et al., 1997). Other cultivars can be grown using plastic tunnels (Bal et al., 1997).

In southern climates, cultivars with a very low chilling requirement, such as southern highbush blueberry or rabbit-eye blueberry (*V. ashei* Reade), are best for profitable cultivation (Reeder et al., 1998).

The specific site and soil requirements of *Vaccinium* species limit commercial growing. *Vaccinium* species need well drained acid soil (pH_{KCl} 3.5-4.0) with a high content of organic matter. Because of their shallow root systems, they need soils which are well aerated and sufficiently moist in the upper layer. They can be grown on many different soil types (Korcak, 1989; Moore and Clayton-Greene, 1993), which may require pH adjustment or the addition of organic matter before planting. Applying sulfur is a good way to lower the soil pH (Moore, 1993). Adding organic matter and mulching with peat, sawdust, bark, or moss also help lower soil pH. Organic matter also improves soil structure. The range of sites amenable to blueberry production could be extended by breeding for upland soil adaptability, optimizing management techniques, and amending upland soils (Korcak, 1988; Finn et al., 1993; Dale et al., 1989; Goulart et al., 1997).

Environmental stresses (wind, cold, drought, flooding and mineral deficiencies) have negative impacts on plant growth, which need to be reduced. **Wind** may drastically limit plant development (Percival et al., 2002), and may be reduced by natural windbreaks, such as forests or single rows of trees, or by artificial windbreaks. **Cold** can damage plants both in winter, depending on the temperature schedule and snow cover, and in spring, when the plants blossom. Overhead irrigation can protect flowers and fruits against frost (Lyrene et al., 1997). **Water** availability can be improved by irrigation and mulching. Standing water can damage blueberry roots, and even kill the plants, depending on cultivar and time of flooding (Silva et al., 1999; Lin et al., 2002). **Mineral deficiencies** can be reduced by fertilizing, by incorporating organic matter into the soil, and by mulching.

2. Plants

High quality, healthy, vigorous plants which are free from viruses and which have good roots should be selected for planting, because they are more resistant to stress. Some cultivars are especially cold hardy and relatively resistant to diseases and pests, even during rainy seasons.

3. Management after planting

Rational use of water, fertilizers, chemicals, and other inputs ensures sustainable crop production with minimal damage to the environment. In blueberry production, weeds may be controlled by clean cultivation with mechanical weed control, or by using grassed-down rows or mulches such as peat, bark, sawdust, or moss. **Mulching,** which also conserves soil moisture, is the most widely used method of weed control (Schmidt, 1989). In the USA, mulching with about 15 cm of milled pine bark is recommended, although less expensive mulches have also been tested (Krewer et al., 2002). Mulching and soil amendment increase plant growth and vigor (Dale et al., 1989; Goulart et al., 1995; Mercik et al., 1995; Pliszka et al., 1993), sometimes even more so than fertilizing (Scibisz et al., 1998).

Synthetic mulches can be used in organic production, but are not as good as pine bark or peat (Norden, 1989; Starast et al., 2002). The best synthetic mulch is non-woven fabric, although black plastic is also good.

Individual growers need to visually examine their blueberry or cranberry plants and chemically analyze soil and leaves in order to determine the best fertilizing levels and schedules. *Vaccinium* species need much less fertilizer than other fruit crops. Care in using nitrogen fertilizers can minimalize damage to the environment, especially to groundwater. Ammonium sulfate is the best fertilizer because it contains readily available nitrogen and is more effective in the root zone (Finn et al., 1997). However, the choice of nitrogen fertilizer does not significantly effect the concentrations of nitrogen and other elements in leaves (Finn et al., 1997; Clark and Naraguma, 1998). Nitrogen absorption appears to be affected more by the plant demand than by soil availability (Throop and Hanson, 1997). Nitrogen is most effectively absorbed during active plant growth, between late bloom and fruit maturity. Applying nitrogen to the soil is far more effective than applying nitrogen to the leaves. (Widders and Hancock, 1994). Fertilizing in divided doses is better both for plant growth and the environment than fertilizing in one large single dose (Hanson and Retamales, 1992. Virgin acidic soils need to be fertilized for successful blueberry production (Austin and Bondari, 1989). Decomposition of soil organic matter releases nitrogen in two forms: ammonium and nitrate. Release rates depend on soil temperature, moisture, and organic matter content (Hart et al., 1994). Ammonium, the initial product of the breakdown of soil organic matter, is the form preferred by *Vaccinium* plants, because they are acidophilic (Smith, 1993; Claussen and Lenz, 1999). Much more nitrogen is released in organic soils than in mineral soils (Davenport and DeMoranville, 1997). Over-fertilization with nitrogen does not reduce fruit yield and fruit quality of plants growing in organic soils as much as it reduces fruit yield and quality of plants growing in other soils (Davenport, 1996;1997). Preliminary results from a trial in Skierniewice indicate that the 'Pilgrim' cultivar grew vigorously and suffered much less pre-harvest and post-harvest fruit rot when not fertilized or fertilized at low rates of nitrogen, than when fertilized at high rates. (Krzewińska et al., unpublished).

Different cultivars respond similarly to mineral fertilization when grown on sterile peat in the absence of mycorrhizal fungi (Eccher et al., 2002). The presence of **mycorrhiza** greatly increases the uptake of minerals, especially nitrogen and phosphorus. Symbiosis between blueberries and fungi increases nitrogen and phosphorus absorption, as well as resistance to stress and pathogenic microorganisms (Koron et al., 2000). Mycorrhizal plants can grow in soils too poor for most other plant species. The level of mycorrhiza formation depends on species and cultivar, as well as on soil type (Noé et al., 2002). There are multiple interactions between cultivar, fungus and fertilizer. Mycorrhiza plays an important role in the ecology of wild plants. In commercial production, mycorrhiza reduces the amount of fertilizers and other chemicals needed, which is important for the development of sustainable agriculture (Noé et al., 2002).

Irrigation depends on rainfall and temperature, especially in poor, sandy soils. Irrigation improves growth and yield (Holzapfel et al., 1997; Holzapfel and Hepp, 2002). The availability of water is critical during fruit formation. In blueberry cultivation, a dry spell after picking can affect production the following year (Perrier et al., 2000). Blueberries require an average of about 25 mm of rain a week, and about 40 mm during the picking season. Cranberries require an average of about 7 mm of rain a week, and about 17 mm during the picking season (Haffner, 1993; Hattendorf and Davenport, 1996).

Pollination increases fruit set and yield, and depends on species and cultivar (MacKenzie, 1997), on weather conditions during flowering, and on the total numbers of pollinators (Eaton et al., 1997). Blueberries and cranberries require insects for pollination (Coville, 1910; MacKenzie et al., 1997).

High density planting of highbush blueberries is a good way to maximize production and to reduce the time to full production (Moore et al., 1993; 1994). Standard blueberry plants have to be pruned every year. Removing old, weak and broken branches increases fruit yield and fruit weight, reduces anthracnose rot in berries, and regulates leaf/fruit ratio and flower count (Jansen et al., 1997; Lyrene et al., 1997; Smolarz and Paal, 1998; Smolarz and Chlebowska, 2002; Hanson et al., 2000; Suzuki et al., 1998).

Earlier harvests are possible if plastic tunnels are used. Later harvests are possible if rain covers are used, especially with late-maturing cultivars (Bal et al., 1997), although improved fruit storage techniques in a controlled atmosphere have reduced the need for this.

4. Plant protection

Vaccinium species are more resistant than other plants to diseases and pests. Nevertheless, the plants constantly need to be visually monitored for a great number of pests and diseases. Symptoms can vary widely depending on cultivar, stage of growth, and application method. Synergistic effects are possible. For example, plants infected by *Botryosphaeria dothidea* after being injured by the cold are even smaller than if they had only been injured by the cold (Cline, 1995; Cline et al., 1997).

In the USA, different diseases predominate in different parts of the country. Cottonball (*Monilinia oxycocci = (Monilia oxycocci)*) is a serious disease in Wisconsin (Caruso and Ramsdell, 1995). Early rot (*Phyllosticta vaccinii*) and bitter rot (*Glomerella cingulata*) are serious in Massachusetts (Qudemans et al., 1998). Fruit rots caused by *Colletotrichum acutatum* (anthracnose), *Alternaria* spp. and *Botrytis cinerea* are serious in Michigan (Schilder et al., 2002). Sunscald, insects, and mechanical damage can make plants more susceptible to rot. Fruit rots are difficult to control. They are usually controlled with fungicides (Schilder et al., 2002). It is important to confirm which pathogens are present before deciding on a control program. It is also important to use as little pesticide as necessary, and to apply it in the most efficient manner possible. For example, when an over-the-row sprayer is used, only one-third the amount of fungicide is needed than when a conventional sprayer is used (Hanson et al., 1997; 2000).

In North America, mummy berry (*Monilinia vaccinii-corymbosi (=Monilia vaccinii-corymbosi)*) is one of the most important fungal diseases (Eck, 1988). Horticultural cultivars can be crossed with wild species to produce cultivars which are more resistant to mummy berry (Stretch et al., 2001). Growing disease-resistant cultivars is economically and environmentally wise, because the need for fungicides is reduced, or even eliminated (Ehlenfeldt and Stretch, 2002).

Little is known about blueberry and cranberry diseases in Poland, even though the cultivation of *Vaccinium* species has increased. In one grower's opinion, there are two or three diseases in Poland, none of which is difficult to control (H. Karwowska, personal communication).

Knowledge of the habits and life cycles of pests is essential for effective control (Cockfield and Mahr, 1994). Some pests can be controlled by using natural enemies, commercially-raised parasitoids (Simser, 1994; Mitchell et al., 1999; Polavarapu et al., 2000), green sphere boards, or pheromone blends (Cockfield et al., 1994; Liburd et al., 2000).

Some blueberry cultivars are more susceptible to larval infestation because of interactions between the life-cycles of both plant and pest. For example, *Rhagoletis mendax* lays it eggs when mid-season cultivars are ripening (Liburd et al., 1998).

Flooding and sanding are two interesting, ecological methods of pest control in cranberry growing. Flooding during spring reduces the number of *Rhopobota unipunctana* larvae (Cockfield and Mahr, 1992), and decreases fruit rot and *Acrobasis vaccinii* infestation (Averill et al., 1997). Applying 1.3 cm of sand to the surface of *V. macrocarpon* plantations controls insect pests without decreasing yield (Davenport and Schiffhauer, 2000). Applying at least 2.5 cm of sand controls swamp dodder (*Cascuta gronovii*, Sandler et al., 1997.)

Viruses can cause enormous damage because they spread so quickly. It is practically impossible to eliminate all sources of all viruses. Viruses are often transmitted by aphids (Bristow et al., 2000).

Birds are another serious problem in *Vaccinium* production. They are extremely difficult to control, although using bird netting before fruit ripening is the most effective treatment, according to a study carried out in the USA (Vincent and Lareau, 1993; Curtis et al., 1994). Sucrose accumulation in fruits deters birds, and could be a valuable addition to current strategies of bird control (Darnell et al., 1994).

On ecological farms, plants can be protected only with mechanical methods, such as removing damaged canes, protecting beneficial fauna, netting against birds, and planting new, multi-resistant cultivars.

CONCLUSION

In ecology-friendly *Vaccinium* cultivation, attention must be paid to:

- site selection;
- multiple resistance of cultivars to diseases, pests and cold;
- improvements in weed control (mulching, sanding);
- improvements in disease, pest and bird control, (natural enemies, pheromones, netting);
- nutrient management (organic matter incorporation and fertilization based on analysis of leaf tissue);

- water management (including overhead sprinklers for frost protection);
- yield improvement (pruning, thinning, improving flower bud set and fruit size).

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EKOLOGICZNA UPRAWA ROŚLIN WRZOSOWATYCH (*Vaccinium*)

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STRESZCZENIE

Na całym świecie żywność określona jako 'naturalna' lub ekologiczna cieszy się coraz większym zainteresowaniem. Rośliny wrzosowate (*Vaccinium*) ze względu na małe wymagania pokarmowe i relatywnie słabe porażenie przez choroby i szkodniki można uznać za szczególnie proekologiczne wśród roślin sadowniczych. W warunkach naturalnych rośliny wrzosowate rosną na glebach ubogich, kwaśnych lub bardzo kwaśnych, o niskim zmineralizowaniu. System korzeniowy pozbawiony jest włośników, a ich rolę spełniają młode, drobne korzonki, na których rozwijają się grzyby mikoryzowe. Rolą grzybów mikoryzowych jest enzymatyczny rozkład substancji organicznych, dzięki czemu udostępnione są dla roślin mineralne formy składników pokarmowych, zwiększa się ich tolerancja na stres i patogeniczne mikroorganizmy. Owoce zawierają wiele cennych składników, m.in. pektyny, kwasy organiczne, polifenole i antocyjany.

W proekologicznej produkcji wrzosowatych należy zadbać o: wybór właściwego stanowiska, wybór odmian o dużej odporności na choroby, niechemiczną ochronę przed chwastami (ściółki, napiaszczanie) i szkodnikami (naturalni wrogowie, feromony, siatki), nawożenie (organiczne i mineralne na podstawie analiz chemicznych liści) oraz zabiegi agrotechniczne (nawadnianie, cięcie, przerzedzanie).

Uprawa wrzosowatych może zwiększyć bioróżnorodność sektora rolniczego i wzmocnić ekonomicznie małe, rodzinne farmy.

Słowa kluczowe: *Vaccinium*, środowisko, mikoryza, ściółki, nawożenie, ochrona roślin