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Review

Breeding Trends of Fruit and Vegetable Crops for Organic Production in Lithuania

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Abstract: At the Institute of Horticulture, Lithuanian Research Centre of Agriculture, Babtai, Lithuania, 27 fruit cultivars and 25 vegetable cultivars suitable for organic production were included in the National Plant Variety List and into the European Union Common Catalogue of Agricultural Plant and Vegetable Varieties. The cultivar development programs have focused on improving cold hardiness, resistance to diseases and pests, and yield, as well as on shipping, shelf life qualities, plant development, and biotechnological applications.

Keywords: breeding; cultivar; orchard plants; vegetables; biotechnology; genetics

1. Introduction

Climatic conditions and the socio-economic environment have given rise to unique horticultural traditions characteristic to Lithuania. Plant breeding for organic production has been an important activity at the Institute of Horticulture, Lithuanian Research Centre of Agriculture and Forestry (IH-LRCAF) in Babtai, Lithuania. The cabbage breeding program was started in 1924, onion in 1926, legume crops in 1929, pear in 1940, blackcurrant in 1946, root crops in 1948, apples and stone fruits in 1952, and strawberry in 1953. The efficiency of horticultural plant breeding depends on scientific progress in the following areas: speeding up generation times, creation of screening methods for valuable characters in the earliest plant development stages, investigation of genetic control mechanisms of plant characters and valuable properties, and development of methods for creation of initial breeding material. In breeding efforts directed toward interspecific crossing, selection of acceptable hybrids, male sterility and creation of stable lines are important issues [1]. The breeding program is focused on pest and disease resistance, quality traits, productivity, biochemical composition, tolerance of unfavorable environmental factors, and adaptability to local agro-climatic conditions [2–6]. Successful cultivar development depends on the availability of genetic material, knowledge of important plant traits, and methods of breeding. Biotechnological methods, based on the newest achievements in genetics, physiology and biochemistry provide new possibilities for breeding. Biotechnology and molecular techniques may guarantee production of high quality fruit and vegetable cultivars [7,8].

The aim of this paper was to review fruit and vegetable crop breeding, investigations of gene pools, and creation of new cultivars and hybrids at IH-LRCAF in Lithuania.

2. Breeding Efforts

Crossbreeding and individual or family group selection have been used for fruit and vegetable breeding. Mass selection has been employed in primary seed production for maintenance of valuable family features as long as possible. Primary breeding material and first generation hybrids have been obtained. A description of the cultivars that were created is reported below, including 7 blackcurrant (*Ribes nigrum* L.), 2 strawberry (*Fragaria* × *ananassa* Duch.), 3 apple (*Malus domestica* Borkh.), 3 pear (*Pyrus communis* L.), 4 sweet cherry (*Prunus avium* L.), 2 sour cherry (*Prunus cerasus* L.), 5 plum (*Prunus domestica* L.), 5 carrot (*Daucus carota* L.), 3 red beet (*Beta vulgaris* L.), 2 radish (*Raphanus sativus* L.), 3 cucumber (*Cucumis sativus* L.), 4 tomato (*Solanum lycopersicum* L.), 2 sweet pepper (*Capsicum annuum* L.), and 2 garlic (*Allium sativum* L.) cultivars, and 1 each white cabbage (*Brassica oleracea* L.), onion (*Allium cepa* L.), chive (*Allium schoenoprasum* L.), and bean (*Phaseolus vulgaris* L.) cultivar. The study was carried out in the experimental fields for organic and conventional horticultural plant production at the IH-LRCAF.

3. Results

3.1. Fruit Crops

3.1.1. Pome Fruits

The genetic origin of resistance to apple scab, one of the most damaging diseases of apple worldwide, caused by the fungal pathogen *Venturia inaequalis*, was tested at the embryonic apple development stage using isolated cotyledons. Application of the method allows a 92%–100% recovery of progeny and provides a valuable tool for efficient assessment of disease resistance [9]. Screening methods of scab-resistant genotypes by using cotyledons in vitro were employed for estimation of donor characteristics and potential for breeding and preliminary estimation of interaction of nuclear and cytoplasmic genes. Donors of monogenic V_f and V_m resistance to *Venturia inaequalis* were introduced into the breeding program. Marker-assisted selection (MAS) has been extensively used in apple breeding to identify inherited resistance genes and to reduce the time required for selection of resistant seedlings, and it is also an important tool for searching for resistance donors. The most commonly used markers were based on SSRs and SNPs. This led to new scab-immune apple cultivars. Each of these cultivars was suitable in yield, storage life and fruit quality. DNA analysis using a *Vfa*1 gene-like sequence-specific marker was performed.

Our results showed that the cultivars "Aldas", "Skaistis" and "Rudenis" were immune to *Venturia ineaqualis* races 1 to 5, and had a DNA fragment of 500 bp specific for the *Vfa*1 gene. The evolving virulence of the apple scab pathogen stimulated efforts to adapt new resistance breeding approaches, such pyramidization of resistance genes. A total of 159 apple hybrids with pyramidic resistance were obtained: 133 seedlings carried *Rvi5* and *Rvi6* genes, and 26 hybrids inherited *Rvi5* and *Rvi10* genes [10,11].

Fruit production and quality and scab resistance are important directions of the pear breeding program. Crossing of local with introduced cultivars has resulted in new pear cultivars, such as "Lukna", "Gaisra" and "Liepona" [12].

3.1.2. Stone Fruits

Crossing local, cold-resistant and disease-resistant cultivars developed abroad has led to the creation of the sweet cherry cultivars "*Jurgita*", "*Mindaugė*", "*Jurga*", "*Meda*" [13], the sour cherry cultivars "*Vytėnų žvaigždė*" and "*Notė*" [14], and the plum cultivars "*Gynė*", "*Jūrė*", "*Rausvė*", "*Kauno vengrinė*", and "*Aleksona*" [15]. A testing protocol for differentiation of resistance to brown rot (*Monilinia fructicola*) in sweet and sour cherry genotypes was developed, and is being applied for development of new sweet and sour cherry cultivars resistant to the disease.

3.1.3. Small Fruits

Organic blackcurrant production requires cultivars resistant to fungal diseases and pests. The limiting factor is lack of resistance in *R. nigrum*, as plants of other *Ribes* species are often more resistant to key pests and diseases. Therefore, interspecific hybridisation has been used to introduce resistance to pests and diseases into commercially-acceptable blackcurrant cultivars [16]. An investigation of inheritance of disease resistance in interspecific hybrids of *R. americanum*, *R. aureum*, *R. janczewskii*, *R. nigrum*, *R. pauciflorum*, *R. petraeum*, *R. sanguineum*, *R. ussuriense* and *R. uva-crispa* resulted in a large number of the hybrids displaying resistance to powdery mildew, a small percentage showing resistance to *Septoria* leaf spot, and no plants demonstrating any resistance to anthracnose.

Large scale hybridizations of the progeny were made with hybrids from the *R. nigrum* spp. scandinavica line. Breeding with this line for resistance to fungal diseases led to the development and release of a number of powdery mildew-resistant blackcurrants. An improvement in blackcurrant quality achieved during past decades has included an increase in average fruit size from 0.9 to 1.5 g, and a 5 to 7 days advancement of flowering time [17]. The new cultivars include:

"*Gagatai*" ("*Minaj Shmyriov*" × "*Öjebyn*"). The fruit are large (1.3 g), and very rich in ascorbic acid (197 mg/100 g) and other chemical compounds. Plants are highly resistant to frost, powdery mildew, and gall mite (*Cecidophyopsis ribis*).

"*Pilėnai*"("*Minaj Shmyriov*" × "*Öjebyn*"). The fruit are large (1.0 g), and contain 153.1 mg/100 g ascorbic acid. The cultivar is highly resistant to powdery mildew, of medium resistance to leaf spot, and slightly affected by gall mite.

"*Tauriai*" ("*Titania*" × "*Beloruskaja Sladkaja*"). The fruit are large (1.5 g), and contain 161 mg/100 g ascorbic acid. Plants are highly resistant to powdery mildew and gall mite.

"*Blizgiai*" ("*Öjebyn*" × "*Minaj Shmyriov*"). The flowering and ripening seasons are earlier than of the cv. "*Minaj Shmyriov*" (1–4 days). The fruit are large (1.5 g), and contain 176 mg/100 g ascorbic acid. The cultivar is resistant to powdery mildew and gall mite in blackcurrant cultivars in Lithuania started in the 1960″s [18]. To overcome the gall mite problem, a new direction in development of genetic lines was initiated by hybridization with the Siberian blackcurrant lineage and selection for field resistance to gall mite. This led to the release of the complex gall mite resistant cultivars "*Vakariai*" and "Dainiai". The main purpose of the breeding program for resistance to gall mite was to introduce the *P* gene from *R. nigrum* spp. *sibiricum* into *R. nigrum*. At the beginning, the agronomic traits of hybrids resistant to gall mite were poor, but these hybrids were backcrossed, and later three commercial cultivars, "*Dainiai*", "*Kriviai*" and "*Kupoliniai*" [19,20], were released. "*Dainiai*", released in 2001, is a cultivar with high fruit quality and complete resistance to gall mite, and was also used as a donor of resistance to gall mite. Progeny of "*Dainiai*" were used to map the *P* gene. A 107 bp AFLP marker was identified and its potential in screening progeny for resistance to gall mite hybrids was evaluated [21].

The breeding program for strawberry involved hybridization with European cultivars. PCR-based markers for the *Rpf1* gene were developed and used for screening strawberries for red stele resistance. Two cultivars, "*Dangė*" and "*Saulenė*", were created, distinguished by their good resistance to fungal diseases, good size and taste, and high yield [22]. A concentrated and high yield with excellent tasting fruits are characteristic of "*Saulene*" ("*Shuksan*" × "*Senga Sengana*"), suitable for fresh use. The mid- to late-season cultivar "*Dange*" ("*Venta*" × "*Redgauntlet*") distinguishes itself by good fruit size, attractiveness, and stable, high yield every year. New wild strawberry cultivars were developed and submitted for DUS testing (Distinctness, Uniformity and Stability) in Poland.

3.2. Vegetable Crops

3.2.1. Root Vegetables

Investigations of carrots and red beets under different production techniques showed that carrot production was less dependent on technology. The total yield of all cultivars of carrots was higher in a conventional system. The greatest differences were obtained with the cultivar "Šatrija BS", with yield

of 48.3 t/ha grown conventionally and 41.0 t/ha grown organically (Table 1). The remaining varieties were less variable. Marketable production was also less varied.

Table 1. Carrots and red beet productivity in Lithuania, Babtai, 2010–2014.

Cultivars	Organic Production		Conventional Production	
	Total Yield (t/ha)	Marketable Production (%)	Total Yield (t/ha)	Marketable Production (%)
Carrot				
"Ieva" H	65.5	88.9	70.0	90.0
"Rokita" H	50.7	88.0	65.3	89.8
"Svalia" H	53.2	87.1	57.7	88.4
"Garduoles"	57.0	87.5	60.0	88.5
"Šatrija BS"	41.0	84.2	48.3	85.4
LSD_{05}	3.186		4.224	
Red beet				
"Joniai"	34.1	75.9	47.2	79.9
"Rikiai"	41.3	82.8	55.5	86.8
"Ilgiai"	40.0	79.4	51.0	80.3
LSD_{05}	7.272		2.469	

Carrot cultivars of the Nantes type are the most popular in Lithuania. Therefore, attention was given to root shape. Roots of the new varieties ("Ieva" H, "Rokita" H, "Svalia" H, "Garduolės", "Šatrija BS") are medium in size and diameter, with a cylindrical, pointed shape. Carrots in Lithuania grow well in a light soil, but the hybrid "Rokita" grows well in a heavier soil. Carotene accumulation ranges from 20–22.5 mg/100 g, dry soluble material from 11%–12.5%, and total sugar from 7.5%–8.5%. Carrots are suitable for harvesting in autumn and for storing [23,24].

Red beet cultivars of different types were created at the Institute [25,26]. The cultivar "Joniai" is distinguished by its small foliage, round and oval-round shape of the root, and not clearly concentrated rings [27]. "Ilgiai" is of medium size with emerald green leaves, with medium-long cylindrical roots. "Rikiai" is a medium early two-seeded (75%) cultivar. The colour of the foliage is dark green with a light yellow tone. The shape of the root is elliptical to round-elliptical with a thin main root with regular skin. "Rikiai" are tolerant to the drought [28]. All new cultivars are suitable for fresh use, storing, and processing.

Cultivars of radish were distinguished by their earliness. Extra earliness is characteristic of "Babtų žara". Its root is round to oval-round, the colour is bright red, the flesh is white, juicy, and delicate in taste. The radish "Liliai" represented medium earliness and has a longer growing cycle. They are suitable for growing in the open field and in greenhouses. Sowing time is possible early in spring or the second and third weeks of August. Roots are round, massive, and red in colour with a purple tone.

3.2.2. Fruit Vegetables

The new cucumber hybrids "Gintai" and "Krukiai BS" are suitable for growing in the open field and in greenhouses [29,30] "Gintai" is a mid-season heterotic hybrid with high yield. It has external attractiveness, is 7–10 cm long, and is light green in colour. "Krukiai BS" is a mid—to late-season hybrid. The fruit is green with white stripes, and does not turn yellow for a long time. The fruit is 8–10 cm long with a diameter of 3.5–4.0 cm. Bees are necessary for pollination. "Daugiai" is distinguished with early ripening and intensive yield. The fruit is 10–13 cm long, dark green, and does not turn yellow for a long time. They are suitable for the fresh market and pickling. Production is optimal in spring and summer in greenhouses.

The new tomato cultivars "Svara", "Viltis", "Balčiai" are suitable for growing in unheated greenhouses and in the open field. "Svara" is a late-season cultivar distinguished with high yield and fungal disease resistance. Fruit are red and weigh approximately 70 g. The fruit are round, and taste somewhat acidic. The cultivar "Viltis" is early ripening. Plants are of medium height and have a short duration of production. Fruit weight at first harvest reach 120–150 g, and later weights decrease to 80–90 g. Fruit are red with a sweet taste, and are flat-round. "Balčiai" is a mid-season cultivar with fruit having red colour, good taste, medium size (75–95 g), with a flat-round shape. "Skariai" is a mid-season cultivar suitable for growing in unheated greenhouses. Fruit are tasty, red in colour, thin skinned, are oblong-oval, cylindrical, and massive (90–150 g). It is sensitive to lack of fertilizer. "Rutuliai" is a mid-season, tall cultivar with red, round, mid-sized fruit. They are suitable for growing in the unheated greenhouses.

Cultivars of sweet pepper "Alanta" and "Reda" are mid-season with a plant height of 0.75–0.80 m, and are self-pollinating [31]. The cylindrical fruit of "Alanta" are distinguished with massive, orange, tasty fruit. This variety is suitable for growing in unheated greenhouses. The shape "Reda" is cut-cylindrical, with external attractiveness, and dark red colour. It grows well in unheated greenhouses, under covers of plastic film, and in the open field.

3.2.3. Onions

In *Allium* L. breeding, the new cultivars "Žiemiai" and "Vasariai" of garlic were created. A flat-round bulb shape is typical for "Žiemiai", the outer skin of the bulb is white, and the cloves are big with 6–9 pieces in a bulb. Bulbils are small, about 150–170 in an inflorescence. The cultivar is disease and pest resistant. "Vasariai" is a mid-season cultivar suitable for planting in spring. The outer skin of the bulb is white, and the bulb consists of 10–16 cloves that are arranged and concentrated into two rounds. The bulb size is 21–27 g.

Homozygotic lines of onions were created by applying a gynogenesis method [32,33]. The cultivar "Babtų didieji" is a mid-season type, with bulbs suitable for fresh use, storage, and processing. The shape of the bulb is round, it weighs 95–116 g, the skin is yellow-orange, and the fresh is white and mildly sweet.

The chive "Aliai" is a perennial plant grown as a bunch. Leaves of "Aliai" start growth early in spring, and the first yield can be harvested 20 days later. Leaves are suitable for fresh use until flowering. The leaves of this cultivar are thin, small and tasty.

3.2.4. Cabbage

The white cabbage "Bagočiai" is a mid- to late-season cultivar. The shape of the head is oval or flat-oval. The colour of the outer leaves is grey-green. "Bagočiai" is distinguished with a good biochemical composition. They are suitable for pickling. Fresh heads can be stored until March.

3.2.5. Legumes

The bean "Baltija" belongs to the bush pod group. The cultivar has a mid-early season. The pod length may reach 11–13 cm. Pods are straight or straight-curved. Seeds are white and oblong. The weight of 1000 seeds is 300–350 g.

4. Conclusions

Cultivars deemed best suited for organic production include: blackcurrant ("Gagatai", "Pilėnai","Tauriai", "Blizgiai", "Vakariai", "Dainiai", "Kriviai", "Kupoliniai"), strawberry ("Dangė" and "Saulenė"), apple ("Aldas", "Skaistis", "Rudenis"), pear ("Lukna", "Gaisra", "Liepona"), sweet cherry ("Jurgita", "Mindaugė", "Jurga", "Meda"), sour cherry ("Vytėnų žvaigždė", "Notė"), plum ("Gynė", "Jūrė", "Rausvė", "Kauno vengrinė", "Aleksona"), carrot ("Ieva" H, "Rokita" H, "Svalia" H, "Garduolės", "Šatrija BS"), red beet ("Joniai", "Rikiai", "Ilgiai"), radish ("Babtų žara", "Liliai"), cucumber ("Gintai", "Krukiai BS", "Daugiai"), tomato ("Svara", "Viltis", "Balčiai", "Skariai"),

sweet pepper ("Alanta", "Reda"), garlic ("Žiemiai", "Vasariai"), white cabbage ("Bagočiai"), onion ("Babtų didieji"), chive ("Aliai"), and bean ("Baltija"). In addition, the new vegetable cultivars were included in the EU Common catalogue of varieties of vegetable species in 2015.

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