Plant breeding in Croatia - achievements and outlook

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Croatia used to be a part of the Austro-Hungarian empire until the World War I. During that time the European agriculture had an influence on the Croatian agriculture. More pronounced application of European agricultural novelties in Croatia followed establishing several agricultural associations during first half of the XIXth century and Royal High School for Agriculture and Forestry (in Kri•evci) in 1860. Leading in improving agriculture were large land owners. One of the approaches to improve agricultural production on their estates was introduction of new varieties. Some of the introductions were later used as germplasm in plant breeding.

Breeding work until World War II

Some plant breeding work was done in Croatia like in other European countries, before the XXth century. The earliest known Croatian variety was maize variety Stra•imirovac. It was selected by the priest Dragutin Stra•imir from the progeny of the variety Little Klai (of American origin) and local maize germplazm by middle of the XIXth century (PARLOV and MARTINCIC, 1996).

After rediscovery of Mendel the first Croatian plant breeder - scientist was Gustav Bohutinsky, a professor at the Royal High School for Agriculture and Forestry in Kri•evci from 1904 to 1914 (MARTINIC-JERCIC 1998). He selected the wheat variety Sirban Prolifik. Also, BOHUTINSKY and MANDEKI developed the maize variety Kri•evacka Hrvatica.

The most productive Croatian breeders before the 2nd World War were Kori first in Kri•evci and after 1931 in Osijek, and Tavcar in Zagreb. The biggest success of Kori was the wheat variety Osjecka šišulja or U_1 which was grown in former Yugoslavia on as many as 500 000 ha per year before the Italian introductions. Tavcar in addition to teaching at the Faculty of Agriculture Zagreb worked on breeding several crops; maize, wheat, barley, rye and soybean (KUMP, 1956).

Breeding work after World War II

After the 2nd World War most Croatian breeders were students of the academician Tavcar at the Faculty of Agriculture in Zagreb. Majority of them got additional education at various universities in the USA. Plant breeding has been done mostly in the Bc Institute for Plant Breeding and Crop Production in Zagreb (Institute Zagreb) at the Faculty of Agriculture in Zagreb and in the Agricultural Institute in Osijek (Institute Osijek). Breeding several crops was done in the Croatian Agricultural Centre (C.A.C.) in Zagreb as well in the past. Sugar beet breeding was done in the Institute for Sugar Beet in Osijek, potato breeding in the Potato Breeding Station Stara Sušica, and tobacco breeding in the Tobacco Institute Zagreb. Today comercial plant breeding is done in the Institute Zagreb, in the Institute Osijek and at the Faculty of Agriculture Zagreb. There are also two private wheat breeding (Agrigenetics d.o.o. and Jost d.o.o.) and one maize breeding firm (CT sjeme). The Institute Zagreb is a private firm as well.

Breeding goals and procedures

Breeding goals have been set in accordance with the needs of market and the farmers requirements. In breeding development of new cultivars mostly conventional breeding procedures have been used. Breeding procedure has been in accordance with the mode of plant species reproduction, mode of inheritance of the trait to be improved, and the type of cultivar to be developed. It has also depended on financial and human resources. Croatia does not have a national germplasm collection. Most breeders maintain some breeding germplasm and some obtain from other breeders as well as from international germplasm collections.

Croatian breeding results

From the Croatian breeding programs a considerable number of cultivars has been released. Most cultivars have been developed in the Institute Zagreb and in the Institute Osijek.

Crop species

Maize (*Zea mays* L.) is the largest grown crop in Croatia and, a considerable amount of breeding work has been devoted to it. The first Croatian inbred hybred Bc 590 [(Nf9 x N6) x (Bc3 x W153R)] came from the Institute Zagreb in 1963. The hybrid was resistant to Helminthosporium turcicum. Eventually more attention in maize breeding work was payed to stalk rot and to ear rot resistance as well as to the drought resistance. The first maize inbred hybrid from the Institute Osijek was released in 1964. Croatian breeders have developed 240 maize hybrids till 1990, and 146 hybrid since 1991 (*Table 1*). Leading in the number of released hybrids have been the Institute Zagreb and the Institute Osijek. Todays maize breeding goal are hybrids of high and stabile yield, resistant to lodging and main pests and suitable for mechanical harvesting. There are programs to develop hybrids for special needs too, i.e. popcorn and sweet corn. In Croatia are grown maize hybrids FAO 200 - 600 (around Zagreb FAO 400, around Osijek FAO 500).

Wheat (*Triticum aestivum* L.) breeding has been also done mostly in the Institute Zagreb and in the Institute Osijek (*Table 1*). After the 2nd World War the first wheat breeding program with the aim to develop semidwarf wheat varietes was started in Zagreb. The most important cultivar from that program was Zlatna dolina (Golden Valey). In the Institute Osijek the first released wheat cultivars

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were Dubravka, Slavonka and some others. Until 1990 Croatian breeders developed 78 and since 1991 122 wheat cultivars. Spring wheat is less grown in Croatia and the released cultivars come from the Faculty of Agriculture Zagreb.

Recently in the Institute Zagreb has been developed a durum wheat breeding program too and three cultivars have been released (*Table 1*). The wheat breeding goals today are high and stabile yield, good baking quality, resistance to lodging and to main pests.

Barley (*Hordeum vulgare* L.) breeding has been done in the Institute Osijek (*Table 1*). All together there were released 17 Croatian cultivars of winter barley until 1990, and 34 cultivars since 1991 and, 15 cultivars of spring barley before and 26 after 1990. Most of the cultivars are two-rowed malting type, some are of feed type and some are for both purposes. Presently aim of breeding both, winter and spring barley is high yield tolerance to most important pests and environmental stresses and quality for malting or for feeding.

Oat (*Avena sativa* L.) breeding has been done in the Institute Zagreb, in the Croatian Agricultural Centre, and at the Faculty of Agriculture Zagreb. All together there have been released 11 oat cultivars since 1990 (*Table 1*).

Breeding goal has been grain and green matter yield, shorter vegetation period, resistant to lodging and to the most important pests. Ray (*Secale cereale* L.) breeding has been of little interest to the Croatian plant breeders and, there were only two domestic ray cultivars released before 1970 (*Table 1*). Triticale breeding has been also of little interest to the Croatian breeders, and has been done in the Institute Zagreb, and there is only one released cultivar. Buckwheat (*Fagopyrum esculentum* L.) breeding was done in Croatia after World War II but has been discontinued. The only Croatian buckwheat cultivar was developed at the Faculty of Agriculture Zagreb (*Table 1*).

Sugar beet (*Beta vulgaris* var. *saccharifera* L.) breeding was done in the Institute Osijek until 1962 and in the Institute for Sugarbeat Osijek until recently. Seven cultivars were released till 1990 and five since 1991. (*Table 2*).

Table 1: **Number of released maize and small grain cultivars in Croatia after World War II**

		Released cultivars		
Agric. crop	Institution	WW II -1990	1991-2004	Total
Maize*Zea mays* L.	Inst. Zg	151	79	230
	Inst. Os	69	47	116
	F.A. Zg	20	-	20
	C.A.C.	-	-	20
	Others	-	20	20
	Total	240	146	406
Winter wheat*Triticum aestivum* L.	Inst. Zg	44	34	78
	Inst. Os	26	53	79
	F.A. Zg	5	4	9
	C.A.C.	-	2	2
	Jost d.o.o.	3	5	8
	Agrigenet. d.o.o.	8	11	19
	Others	-	5	5
	Total	86	114	200
Spring wheat*Triticum aestivum* L.	F.A. Zg	6	-	6
	Total	6	0	6
Durum wheat*Triticum durum* L.	Inst. Zg	-	3	3
	Total	0	3	3
Winter barley *Hordeum vulgare* L.	Inst. Zg	-	2	2
	Inst. Os	17	32	49
	Total	17	34	51
Spring barley *Hordeum vulgare* L.	Inst. Zg	-	2	2
	Inst. Os	11	17	28
	F.A. Zg	4	5	9
	C.A.C.	-	2	2
	Total	15	26	41
Oat *Avena sativa* L.	Inst. Zg	-	4	4
	F.A. Zg	-	2	2
	C.A.C.	-	5	5
	Total	0	11	11
Ray *Secale cereale* L.	F.A. Zg	2	-	2
	Total	2	0	2
Buckwheat *Fagopyrum esculentum* L.	F.A. Zg	1	-	1
	Total	1	0	1
Triticale	Inst. Zg	-	1	1
	Total	0	1	1

Tobacco (*Nicotiana tabacum* L.) (fluecured and barley) breeding has been done in the Tobacco Institute Zagreb and since 1988 also at the Faculty of Agriculture Zagreb. The aim has been high and stable yield, quality acceptable to the world market and resistance to the most important pests. Croatian tobacco breeders developed ten cultivars till 1990 and 25 since 1991 (*Table 2*).

Soybean (*Glycine max* (L.) Merrill) breeding has been done in the Institute Osijek, in the Croatian Agricultural Centre and at the Faculty of Agriculture Zagreb. Twenty five cultivars were released until 1990 and 22 afterwards (*Table 2*). The cultivars are of vegetation group 00-II. Most cultivars have been developed in the Institute Osijek. Breeding goal has been high yield and high percentage of proteins and oil, resistance to lodging and main pests, and cultivars suitable for mechanical harvesting. Sunflower (*Helianthus annuus* L.) breeding has been done in the Institute Osijek and some in the Croatian Agricultural Centre. Until 1990 Croatian breeders developed five and after 1991 eleven sunflower cultivars (*Table 2*). Breeding goal has been resistance to lodging main pests and drought, and high yield of oil and proteins.

Oil rapeseed (*Brasica napus* L.) breeding was done in the Institute Osijek and in the Croatian Agricultural Centre and more recently in the Institute Zagreb. From these programs three cultivars were released till 1990 and five afterwards (*Table 2*).

Chicory (*Chicorium intybus* L.) breeding was curried out in the Institute Osijek after World War II and, two cultivars were developed till 1970 (*Table 2*).

Potato (*Solanum tuberosum* L.) breeding program was started after the World War II in the Potato Breeding Station Stara Sušica. The Station was a part of the Institute Zagreb. Recently, the breeding work has been discontinued. Croatian breeders developed eight cultivars until 1990 and two since 1991 (*Table 2*). Forage legume (*Medicago sativa* L., *Trifolium pratense* L., *Trifolium repens* L., *Lotus corniculatus* L., *Vicia vilosa* Roth, *Pisum sativum* L. var. *arvense*, *Lupinus albus* L.) breeding after World War II was first started at the Faculty of Agriculture Zagreb. Presently it is done in the Institute Zagreb, in the Institute Osijek, and at the Faculty of Agriculture Zagreb. Until 1990 there were released 15 cultivars of alfalfa one of vetch and one of forage peas and since 1991 eight alfalfa, three red clover two white clover, two birds foot trefoil, four forage pea and two cultivars of white lupine (*Table 3*). Generally breeding goal was high green and dry matter yield, good feeding value and persistency.

Forage grass (*Dactylis glomerata* L., *Lolium multiflorum* Lam., *Lolium perenne* L., *Festuca rubra* L., *Festuca arundinacea* L., *Festuca pratensis* L., *Arrhenatherum elatius* L., *Poa pratensis* L., *Phleum pratense*, *Agrostits alba* L.) breeding program in Croatia has been carried out mostly in the Institute Zagreb. Until 1990 eight grass cultivars were released (*Table 3*). After 1991 there have been six grass cultivars released. The cultivars have good yield potential and resistance to low temperatures. They are suitable for growing in mixtures and in pure culture.

Fodder beet (*Beta vulgaris* L. subsp. *sativus*) breeding was carried out in the Institute Osijek and at the Faculty of Agriculture Zagreb. From each program one cultivar was released before 1990 (*Table 3*). Turnip-rooted cabbage (*Brassica napus* L. var. *napobrassica*) and Fodder kale (*Brassica oleracea* (L.) convar. *acephala*) breeding has been done at the Faculty of Agriculture Zagreb. One kail cultivar was released before 1990, and one turnip cultivar since 1991 (*Table 3*).

Vegetable breeding has been carried out in the Institute Botinec near Zagreb, at the Faculty of Agriculture Zagreb, and in Podravka (*Table 4*). From these programs were released one sweet peeper (*Capsicum annuum* L.) cultivar, three

Table 2: **Number of released domestic cultivars of industrial crops and potato in Croatia after World War II**

Agric. crop	Institution	Released cultivars WW II -1990	1991-2004	Total
Sugar beet *Beta vulgaris* var. *saccharifera* L.	I.S.B. Os	7	5	12
	Total	7	5	12
Tobacco *Nicotiana tabacum* L.	T.I. Zg	10	13	23
	F.A. Zg	-	12	12
	Total	10	25	35
Soybean *Glycine max* (L.) Merrill	Inst. Os	14	17	31
	F.A. Zg	7	3	10
	C.A.C.	4	-	4
	Total	25	20	45
Sunflower *Helianthus annuus* L.	Inst. Os	1	11	12
	C.A.C	4	-	4
	Total	5	11	16
Oil rapseed *Brassica napus* L.	Inst. Zg	-	5	5
	Inst. Os	2	0	2
	C.A.C.	1	-	1
	Total	0	0	0
Chicory *Chicorium intybus* L.	Inst. Os	2	0	2
	Total	2	0	2
Potato *Solanum tuberosum* L.	Stara Sušica	8	2	10
	Total	8	2	10

tomato (*Lycopersicum esculentum* L.) cultivars, three lettuce (*Lactuca sativa* L.) cultivars, two bean (*Phaseolus vulgaris* L.) cultivars, and one parsnip (*Pastinaca sativa* L.) cultivar until 1990.

Since 1991 there have been released two sweet paper cultivars, two bean cultivars and one cabbage (*Brassica oleracea* L. convar. *capitata*) cultivar.

Application of biotechnology in plant breeding

Biotechnology has been more subject of research than of use in commercial plant breeding. However, haploid techniques and application of molecular markers have been more and more adapted by the conventional breeders.

Biotechnological gene transfer has not been used in the commercial plant breeding yet. Present state law does not al-

Table 3: **Number of released domestic cultivars of forage crops in Croatia after World War II**

Agric. crop	Institution	Released cultivars WW II -1990	1991-2004	Total
Alfalfa *Medicago sativa* L.	Inst. Zg	2	2	4
	Inst. Os	12	6	18
	F.A. Zg	1	-	1
	Total	15	8	23
Red clover*Trifolium pratense* L.	Inst. Zg	-	2	2
	Inst. Os	-	1	1
	Total	0	3	3
White clover*Trifolium repens* L.	Inst. Zg	-	1	1
	Inst. Os	-	1	1
	Total	0	2	2
Bird's foot trefoil *Lotus corniculatus* L.	Inst. Zg	-	1	1
	Inst. Os	-	1	1
	Total	0	2	2
Vetch*Vicia vilosa* Roth	F.A. Zg	1	-	1
	Total	1	0	1
Field pea *Pisum sativum* L. var. arvense	F.A. Zg	1	3	4
	Inst. Os	-	1	1
	Total	1	4	5
White lupine *Lupinus albus* L.	F.A. Zg	-	2	2
	Total	0	2	2
Grasses	Inst. Zg	8	6	14
	Total	8	6	14
Fodder beet *Beta vulgaris* L. subsp. *sativus*	Inst. Os	1	-	1
	F.A. Zg	1	-	1
	Total	2	0	2
Turnip-rooted cabbage *Brassica napus* L. var. *napobrassica*	F.A. Zg	-	1	1
	Total	0	1	1
Fodder kale *Brassica oleracea* (L.) convar. *acephala*	F.A. Zg	1	-	1
	Total	1	0	1

Table 4: **Number of released domestic cultivars of vegetables in Croatia after World War II**

Agric. crop	Institution	Released cultivars WW II -1990	1991-2004	Total
Sweet pepper *Capsicum annuum* L.	Inst. Botinec	1	2	3
	Total	1	2	3
Tomato *Lycopersicum esculentum* L.	Inst. Botinec	3	-	3
	Total	3	0	3
Lettuce *Lactuca sativa* L.	Inst. Botinec	2	-	2
	F.A. Zg	1	-	1
	Total	3	0	3
Beans *Phaseolus vulgaris* L.	Inst. Botinec	1	-	1
	F.A. Zg	1	-	1
	Total	2	0	2
Cabbage *Brassica oleracea* L. convar. *capitata*	F.A. Zg	-	1	1
	Total	0	1	1
Parsnip *Pastinaca sativa* L	Podravka	1	-	1
	Total	1	0	1

low growing GM cultivars in broad production at the present time.

Outlook for future Croatian plant breeding

The extent of domestic plant breeding programs will depend on the market interested in domestic cultivars. At the present time foreign seed companies, i.e. Pioneer, are more interested in crops where they have control over seed like in maize. Once the law on the status of GMO in Europe changes competition with the international seed companies will be more difficult. Adequate molecular breeding education and training is partly on answer to the future competition on the seed market and Croatian plant breeding firms try to take care of that. Cultivars which contribute to the profitable form production will be more and more looked for which should be taken care of in breeding programs. Seed price influence will influence the farmer's choice of seed-cultivar.

Conclusions

Croatian has a long tradition in plant breeding. In the past, over 700 released cultivars mostly of crop species have come out of the domestic breeding programs. Most productive domestic breeding institutions have been the Bc Institute for Plant Breeding and Production in Zagreb, the Agricultural Institute in Osijek and the Faculty of Agriculture in Zagreb. In addition, at plant breeding is carried out also in two relatively small wheat breeding (Jost d.o.o., Agrigenetics d.o.o.) and one maize breeding firm (CT sjeme). Presently grown domestic cultivars have been obtained through conventional breeding methods. Biotechnology (tissue culture, haploids, molecular markers) are being integrated into the conventional breeding. Education and training of younger breeders for future successful plant breeding is under way.

Literature

KOVACEVI, J., 2004: Plant Breeding in the Agricultural Institute Osijek (manuscript) str. 1-6).

KOZUMPLIK, V. and Z. MARTINI-JERCIC, 2004: Breeding field crops and vegetables in Croatia. Agric. Consp. Sci. 865(2):129-141.

KUMP, M. 1956: Maksimirski rani zuban M 1. U Sorte •itarica i aprobacija usjeva. Milatovi Lj., o urd., Poljoprivredni informator br. 3 za 1956., str. 173.

MARTINCIC, J. and V. KOZUMPLIK, 1996: Plant Breeding - Part II Crop Species. Zagreb.

MARTINI-JERCIC, Z., 1998: Oplemenjivanje pšenice u Hrvatskoj 1904-1997. Referat prigodom Obljetnice Agrariacoop.

PARLOV, D. and Z. MARTINI-JERCIC, 1996: Sorte i hibridi kukuruza. Znanost u Hrvata: prirodoslovlje i njegova primjena. Zbornik 2:512-513.