Heterosis in rye
(Secale cereale L.)

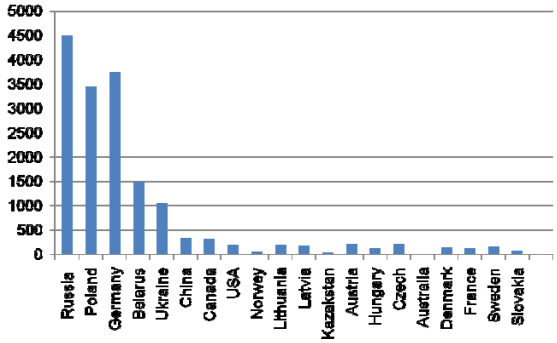
S. HARDZEI

SCIENTIFIC AND PRACTICAL CENTRE OF BELORUSSIAN NAS
FOR ARABLE FARMING,
BELARUS

Phenomenon of "hybrid power" was noticed in XIX century. First it was described by Ch. Darwin. At present heterosis F_1 hybrids were developed for almost all agricultural plants. Moreover, as a rule open-pollinated crops including rye are characterized more higher level of heterosis. Perhaps it's conditioned by presence in open-pollinated crops large reserve of genetic inconstancy.

Researches for genetics and breeding of heterosis rye hybrids are concentrated mostly in Europe, because about 87% of world rye acreage is at this continent. Most considerable results in this field obtained in Germany. At present hybrid varieties occupy about 60% of all rye area in this country. Several German F_1 rye hybrids were registered in Belarus: Picasso; Askari, Fugato, Amato.

The largest rye producing countries in the world in 2009-2011 (th t)



History of practical using of heterosis on rye was started after discovery of cytoplasmic male sterility (CMS).

There are different CMS types (P; G; R; A; C; S; V), which were found in populations from different ecological groups.

Comparative study of various CMS types has shown, that only P-type is characterized by easy sterility maintenance and by low frequency of fertility restoration genes . For other known CMS types - R, G, A, C, S, V - it is difficult to find non-restorers , and with restorers problems do not exist. Wide use in researches of P-type CMS is caused by the big frequency in populations of sterility maintenance genes, as there is no risk to lose in generations sterile forms. Now almost all commercial hybrid cultivars of a winter rye are developed on the basis of P-type CMS.

Exception is CMS of G-type. In 2000 in Germany first line-population F_1 hybrid of rye «Novus», developed on genetic basis of G-CMS (♀ ms-line «Gülzower-1») and population cultivar "Valet" ♂ [9] was registered (Melz Gi., et al., 2001) Later several hybrid rye cultivars on the basis of G-CMS were registered in Germany: Hellvus, Helltop

The main tasks :

Development of inbred-lines collections with high combining ability (GCA and SCA) and with weak inbred depression in generations;

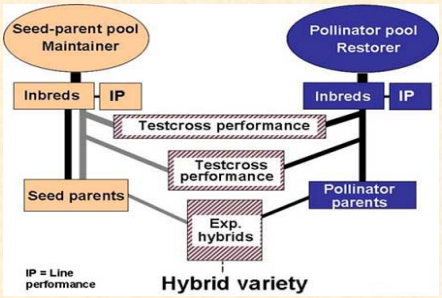
Revealing of sterility maintainers (non-restorers) and restorers;

Development of cytoplasmic male sterility system - CMS - (sterility maintainer + male sterile analogue of a sterility maintainer / ♀/, restorer / ♂/);

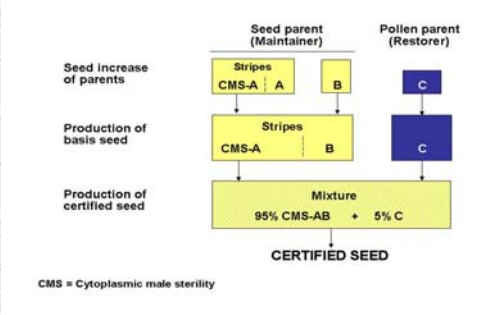
Working out of an effective technique of female (MS) and male components of hybrid cultivar reproduction;

Working out of economically expedient scheme of reception of hybrid seeds and system of seed-growing of hybrid cultivar.

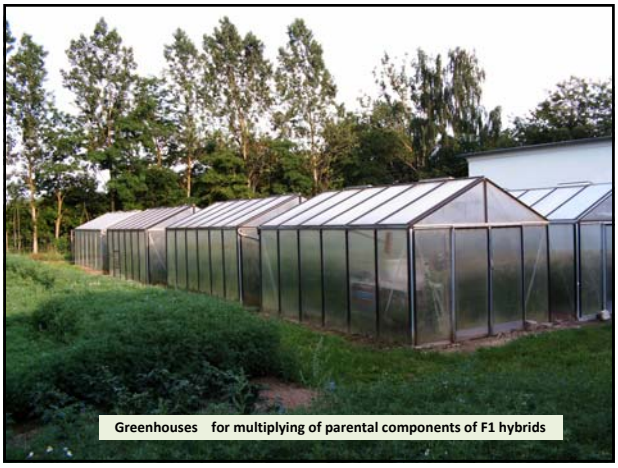
sterility maintainer | **male sterile analogue of a sterility maintainer** | **restorer**

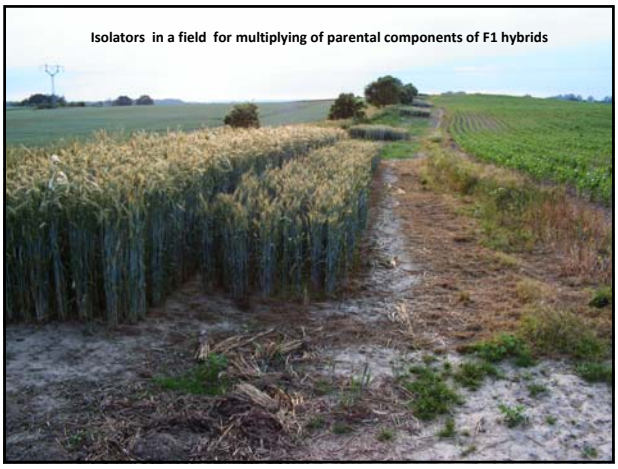


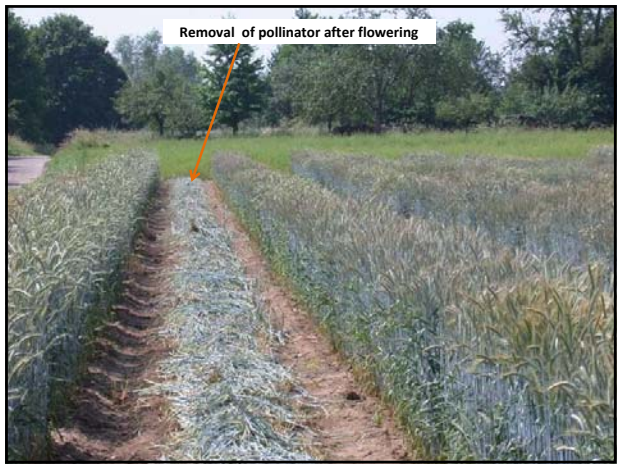
The scheme of a winter rye F_1 heterosis hybrids development. (Geiger, 2007)



The scheme of a rye hybrid seeds production (Geiger, Miedaner, 1999).







The important link in hybrid rye breeding with use of P-CMS is full restoration of pollen fertility of F_1 hybrids . Here there are a number of difficulties. As is known, frequency of fertility restoration genes in rye populations is small. It is established, that fertility of F_1 rye hybrids depends equally as on female and male component

Restoration level of pollen fertility (%) at F_1 rye hybrids.

MS-line, ♀	Restorer, ♂				Average
	4-1	25-1	17-3	Kalinka	
MC-7	97,0±1,2	96,3±1,3	81,5±2,5	91,0±1,8	**91,5**
MC-2	90,2±1,8	87,5±2,3	75,7±3,5	30,6±2,5	**71,0**
MC-13	76,2±2,7	65,5±2,8	62,6±4,4	68,6±2,7	**68,2**
MC-24	69,7±3,0	60,7±2,6	63,7±3,5	57,5±2,4	**62,9**
MC-5	22,4±2,8	24,3±2,3	18,6±2,7	1,5±0,5	**16,7**
Average	**71,1**	**66,9**	**60,4**	**49,8**	**62,1**

As a rule for development of hybrid cultivars researchers use lines characterized by high productivity and not enough by high restoring ability (P-CMS). As result, hybrid cultivars possess insufficiently full level of pollen fertility, that at rainy weather during flowering leads to susceptibility of hybrids to an ergot. To solve this problem it is necessary to add to hybrid seeds about 10% seeds of population cultivar

Practical results of hybrid rye development.

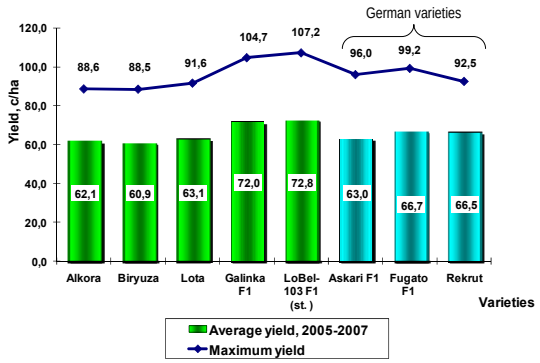
As a result of joint researches of SPCAF (Belarus) and KWS LOCHOW (Germany), first F_1 hybrids of winter rye were developed : LoBel-103, LoBel -203, LoBel -303, which have exceeded the standard on 8,0-14,4 dt/ha (tab.).

Table. Characteristics of heterosis F_1 hybrids of rye (Zhodino, 2004-2005

Traits	Radzima – st.	LoBel-103	LoBel - 203	LoBel -303
Yield, dt/ha	**67,8**	**80,8**	**75,8**	**82,2**
Height, m.	1,35	1,19	1,17	1,18
Lodging resistance, scale (1-9)	7,0	8,0	8,0	8,0
Stem density, stems/m^2	445	575	589	554
Grain weight per spike, g	1,56	1,43	1,39	1,53
Seed-set, %	75	82	84	79
Winter hardiness, %	96,0	90,5	90,3	94,0

First Belorussian F_1 hybrid of rye named Plisa was developed in 2007. During three years of State study this cultivar has shown more higher yield compared to standard LoBel-103 (tab.)

Place of study	Yield, dt/ha		
	LoBel-103 – st.	Plisa	
		dt/ha	±to st, dt/ha
Kamenets	79,6	78,5	-1,1
Lepel	86,5	92,0	+ **5,5**
Oktyabr	50,4	53,5	+ **3,1**
Molodechno	90,9	94,8	+ **3,9**
Gorki	88,1	88,3	+ **0,2**



There are some restrictions at use of a hybrid rye in an agricultural production.

First of all hybrid cultivars demand more rich soils and accurate cultivation technology. On poor sandy soils hybrids are not able to display heterosis.

It's established, that hybrid rye cultivars must display not less than 10% of heterosis to cover the expenses for more expensive seeds of F_1 hybrids compared to population cultivars. Farmers or other agricultural organizations must buy seeds of F_1 hybrids every year. Cultivation of F_2 progeny is not effective because of reduction of heterosis level.

In spite of four German hybrid cultivars (Picasso; Askari, Fugato, Amato) were registered in Belarus, there are not official data about acreages of these cultivars.