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PLANT GROWING

Creation of Initial Material for the Adaptive Selection of Garden Chrysanthemum (*Chrysanthemum hortorum* Bailey) in the Russian Far East

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Abstract—Priority trends in the adaptive selection of the garden chrysanthemum in the south of the Russian Far East are determined. The crossing and introgression of valuable features from the wild species of the *Chrysanthemum* genus into the garden Chrysanthemum genotype (*Chrysanthemum* × *hortorum*) are shown to be possible. Simple interspecific, multicomponent interspecific, and back crosses are approved. The complex adaptive sources and donors of commercially valuable signs have been created. The association of alleles of the wild Chrysanthemum species and varieties by interspecific hybridization has enabled transgressive forms to be revealed to reach the best adaptability.

Keywords: garden chrysanthemum, wild *Chrysanthemum* species, selection trends and methods, Russian Far East

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INTRODUCTION

The garden chrysanthemum (*Chrysanthemum hortorum* Bailey) is a new horticultural group obtained by American selectionists only 80 years ago based on an interspecific hybrid between the greenhouse Ruth Hatton variety and wild *Chrysanthemum* species from Korea [1]. Owing to the unique combination of a number of biological and economic signs from two parents, the synthesized hybrid has become a source of new commercial varieties that are competitive with greenhouse chrysanthemums in resistance, duration, and abundance of flowering [2]. Having spread throughout the world, the garden chrysanthemum has taken a prevalent place in landscape design, topiary art, container culture, and high-quality and productive cutting. However, its open-ground growing is limited in most regions of the Russian Federation, including the Far East. The problem of increasing the adaptive potential of the garden chrysanthemum was not solved in the territory of Russia until now. The low winter resistance of plants is caused genetically: the modern assortment has been obtained in the process of long-term selection based on subtropical species in the mild climate of Eastern Asia, America, and Europe. The photoperiod sensitivity restricts the cultivation of many varieties to the north from the 50° geographical latitude. As a dangerous disease (*Puccinia horiana* Henn.) penetrated into the Primorie territory, a new serious problem arose, which can be solved only by selection methods. The optimal method for removing the counteractions between the biological requirements of introduced varieties and Russian climate conditions can be to involve the wild *Chrysanthemum* species in the selection process and to create, on their basis, principally new domestic garden chrysanthemum varieties with a reliable ecological adaptation and high level of commercially valuable signs.

The goals of the present work were to determine the priority trends in research and to create the initial material for the selection of adaptive garden chrysanthemum varieties in the south of the Russian Far East. The tasks of the studies were as follows:

(1) Concentrate the greatest possible amount of commercial and biological signs in hybrids, using the sources of ecological resistance genes and different types of crosses.

(2) Create a hybrid material on a new genetic basis, which will be accessible for subsequent selection work.

MATERIALS AND METHODS

The studies were carried out at the Botanical Garden Institute (BGI) (Far Eastern Branch, Russian Academy of Sciences) in 2000–2013. Highly decorative garden chrysanthemum varieties ($2n = 54$) with a different ecological geographical origin and different degree of *P. horiana* sensitivity were used as mother parents (Vrodliva, Linda, Stelutsa, Khameleon), and wild species *Chrysanthemum chanetii* Levl. Shih. ($2n = 18$), *C. coreanum* (Levl. et Vaniot) Nakai et Mori ($2n = 54$),

Sources and donors of adaptive signs (adequate flowering period, *P. horiana* immunity, winter resistance) of the chrysanthemum created at the Botanical Garden Institute (Far Eastern Branch, Russian Academy of Sciences) (2000–2013)

Selection number	Origin	Year of selection	Destination	Disadvantages
		F_1		
03-2	Khameleon × *C. zawadskii* var. *tenuisectum*	2004	Complex source and donor	–
05-5	Linda × *C. naktongense*	2005	The same	–
05-7	*C. naktongense* × Linda	2005	"	–
64-06	Vrodliva × *C. coreanum*	2006	"	–
04-9	Khameleon × *C. zawadskii* var. *latilobum*	2005	Complex source	–
05-22	Vrodliva × *C. zawadskii* ssp. *acutilobum* No 5	2005	The same	–
63-06	Vrodliva × *C. coreanum*	2006	"	High height
67-06	Vrodliva × *C. naktongense*	2006	"	Presence of sterile shoots
		F_2B_1		
26-06	Vrodliva × (Vrodliva × *C. zawadskii* var. *tenuisectum*)	2006	Complex source	–
07-09	(Linda × *C. zawadskii* var. *tenuisectum*) × Stelutsa	2009	The same	High height
		$F_1 \times F_1$		
08-66	05-5 × 64-06	2008	Complex source	–
40-12	03-2 × 05-7	2012	The same	–
43-12	05-5 × 04-9	2012	"	–
45-12	05-7 × 04-9	2012	"	–
46-12	05-7 × 03-2	2012	"	–
57-12	05-7 × 05-5	2012	"	–
58-12	05-5 × 05-7	2012	"	—

C. naktongense Nakai ($2n = 36$), *C. zawadskii* ssp. *acutilobum* (DC.) Kitagawa ($2n = 54$), *C. zawadskii* ssp. *acutilobum* var. *tenuisectum* Kitagawa ($2n = 54$), *C. zawadskii* ssp. *latilobum* (Maxim.) Kitamura ($2n = 36$) that are the sources of ecological resistance were used as father parents. The basic theses of the program and methods served as a methodical guide in the selection work [5, 6]. When the hybrid material was created, simple interspecific, multicomponent interspecific, and back crosses with the cultural form were approved: 649 heads were pollinated, 10331 hemicarps were obtained from 114 cross combinations, and 3232 hybrid seedlings were grown. In the first year of growth, *P. horiana* resistant seedlings were selected in hybrid families F_1, ($F_1 \times F_1$) and F_2B_1 against the natural infection background; winter-resistant seedlings were chosen after the first and next winters, and complexly adaptive and decorative seedlings were selected in the third year.

RESULTS AND DISCUSSION

The priority trends in the adaptive selection of the garden chrysanthemum in the south of the Russian Far East are to create the highly decorative varieties that have adequate flowering periods, are resistant to *P. horiana*, and winter in open ground without being covered.

The wide biomorphological and genetic ties of the *Chrysanthemum* varieties and wild species, which have been discovered during the studies, have caused the urgency of introducing the wild relatives in selection [7]. The domestic adaptive selection of the garden chrysanthemum is only starting to develop, and the present studies are at the stage of creating the complex sources and donors that genotypically combine the long-term *P. horiana* resistance, low-temperature resistance, and early flowering at the expense of joining different genetic systems that are immanent to the *Chrysanthemum* species and varieties.

Crosses of the hexaploid ($2n = 54$) and diploid varieties ($2n = 18$) *C. chanetii* and *C. seticuspe* were not successful. The hybridization of the cultural varieties with the wild relatives was revealed to be possible using the tetraploid ($2n = 36$) and hexaploid *Chrysanthemum* species, although its implementation was complicated by a large distinction in flowering periods of used partners and affected the number of set hemicarps. The intercombination variation in the results of crosses was noted, which indicated a complex interaction between the genomes of the initial components and conditions of gametogenesis and embryogenesis. The F_1 hybrid

families of different volume were obtained based on the species *C. coreanum*, *C. naktongense*, *C. zawadskii* ssp. *acutilobum*, *C. zawadskii* ssp. *acutilobum* var. *tenuisectum*, and *C. zawadskii* ssp. *latilobum*. The F_1 progenies differed from the initial parent forms in the hybrid capacity and were fairly monomorphic within a family independently of a cross combination. The signs of the wild species were prevalent as regards a plant habitus, large foliage cover of generative shoots, and intensity of vegetative renewal. The form, size, and color of racemes were also characterized by a phenotypic uniformity and indicated the presence of wild-type dominant alleles. Owing to the sign of white rust resistance (*Ph*) being dominant and inherited monogenically (oligogenically), *P. horiana*-resistant seedlings were obtained in the F_1 progeny based on *Chrysanthemum zawadskii* spp. *acutilobum* var. *tenuisectum*, *C. coreanum*, *C. maximowiczii*, and *C. naktongense*. Plants with a different degree of sensitivity were observed when using *C. zawadskii* ssp. *acutilobum*. Consequently, the *P. horiana* resistance selection has already been carried out in the F_1-hybrid generation in the first growth year.

From amongst *P. horiana*-resistant F_1 hybrids, winter-resistant plants were selected on the genetic basis of *C. naktongense*, *C. coreanum*, *C. zawadskii* ssp. *acutilobum* var. *tenuisectum* (nos. 03-2, 05-5, 05-7, 63-06, 64-06, 67-06). The subspecies *C. zawadskii* spp. *acutilobum* no. 5 and *C. zawadskii* spp. *latilobum* did not promote the growth in winter resistance: most of the obtained hybrids survived only the first winter and singularly (nos. 05-22, 04-9). The obtained adaptive half-cultural F_1 forms also have a number of other positive qualities: they are adequate in flowering periods to climatic conditions, recover well vegetatively (form a strong branched root), are highly decorative, and serve as complex adaptability sources and donors (table).

The saturation of the first hybrid generation (F_1) with the cultural form has strengthened the cultural signs of the hybrid progeny (F_2B_1) and lowered the share of individuals with a wild genotype, but it decreased the intensity of shoot formation and winter resistance: only single specimens survived in open ground as early as after the first winter (nos. 26-06, 7-09). However, the segregation of even single adaptive seedlings indicates the introgression of valuable signs in the wild relatives and gives hope for increasing winter resistance of the future hybrids and varieties, and incites us to obtain many forms with other important commercial and biological properties.

The crosses of F_1-selections based on different *Chrysanthemum* species have made it possible to select in the hybrid progeny ($F_1 \times F_1$) the highly decorative complexly adaptive forms (table) to join the signs of different genetic systems that are complex adaptive sources in the selection work and candidates for new varieties and undergo primary variety studies.

The simple and multicomponent interspecific hybrids and back crosses obtained at the Botanical Garden Institute (Far East Branch, Russian Academy of Sciences) result from joining different genetic systems of the *Chrysanthemum* genus and introgression of the genetic material at the intergenomic level. The diversity of alleles of the wild *Chrysanthemum* species associated in new organisms has promoted the origin of transgressive forms that give an opportunity to pass to a higher level of signs and to obtain principally new varieties of the garden chrysanthemum.

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