Mutation breeding of cineraria using heavy-ion irradiation

S. Ochiai,[*1] M. Ochiai,[*1] Y. Ochiai,[*1] Y. Hayashi,[*2] and T. Abe[*2]

Many new cultivars have been produced by individual growers in flower plants. Since 2000, the largest number of cultivars developed through mutation breeding have been in flowering plants in Japan. Our company produces and tests 20,000 to 40,000 plants annually to develop new cultivars. "Keika" is our most famous cultivar in cineraria (*Senecio cruentus*). Cineraria is a popular potted plant that blooms thickly with colorful flowers from winter to spring. The general type of cineraria is called "Daruma-type" in Japan because its shape is dwarf, and the upper part of the inflorescence is rounded. Most growers have bred cineraria by themselves to obtain its seed for the next season. Cineraria breeding has advanced through this progress. In 1965, we introduced a new type of cineraria developed in the United States, which is suitable for cut flower and has colder resistance than "Daruma-type." It has been cross-bred and selected repeatedly over several decades, and we produced new cultivar called "Keika" with excellent flower color, cold resistance, and flower longevity. A disadvantage of this cultivar is a poor root development during the summer seedling period. In addition to conducting cross pollination and bud mutation selection, we also attempted to induce mutations in cuttings and dry seeds using X-rays and gamma rays (150 Gy, dry seeds). Although flower color mutants were obtained, they were not put to practical use because the root trait was not improved.

In 2013, we irradiated cuttings of "Keika" with a C-ion beam (23 keV/μm) at a dose of 10 and 20 Gy. 2,000 plants propagated by cuttings from 315 M_1 plants were cultivated for mutant screening. We observed morphological mutations, such as flower color and shape, plant height, and leaf color and shape. Although some flower color mutants emerged, none of the were useful. In our research, a useful mutant means a candidate of promising line for the market with good rooting, cold

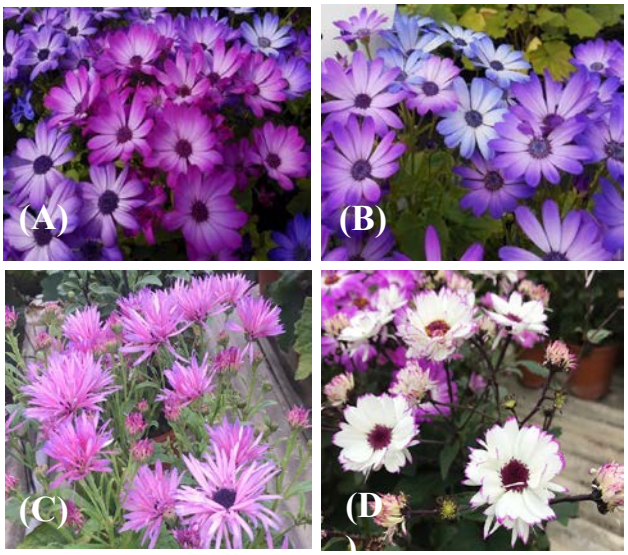

Fig. 1. Mutated plants of cineraria induced by heavy-ion irradiation. (A) Pink flowers in 423 line, (B) blue flowers in 423 line, (C) and (D) double flowers induced by Ar-ion irradiation.

Table 2. Survival rate after Ar-ion irradiation on seeds.

Group	Dose (Gy)	No. of Seeding	No. of Plants	Survival (%)
Blue	10	531	247	46.5
	20	567	249	43.9
	40	588	185	31.5
Pink	20	564	46	8.2
Red	20	220	59	26.8
Others	10	1080	429	39.7
	20	936	360	38.5
	40	760	222	29.2

Table 1. Mutant induced by C-ion irradiation on cuttings.

Line	Flower color	No. of cutting	No. of mutant	No. of useful mutant	(%)	Mutation type		
						Flower-color	Petal-shape	Leaf-color
423	Purple	237	159	37	15.6	Pink, red, blue, pale	Shrinking, Pointed	
424	Purple	251	186	18	7.2	Pale	Thin, small	
521	Red	250	134	9	3.6		Thin, small, deeply jagged	
SL2-11	Pink	164	343	15	9.1		Thin, small, shrinking	
??(P)	Pink	424	296	3	0.7		Shrinking, jagged	
Red-purple	Red	308	276	15	4.9	Pale	Small	Variegated

*1 Hanakongou Co., Ltd.
*2 RIKEN Nishina Center

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resistance, or novelty as an ornamental plant . Next, in 2014, the cuttings were irradiated with 30 and 40 Gy of C-ions, showing a high mutation rate and wide spectrum (Table 1). The 423 line with purple flowers had the highest mutation rate (15.6%) (Fig. 1(A), (B)). The pink flower line exhibited no mutations in flower color, but the root weakness persisted. Therefore, we attempted to irradiate the seeds with an Ar-ion beam (184 keV/μm) in 2021. As a result, the survival rate decreased in all doses and groups, particularly in the 40 Gy irradiation group (Table 2). In the M_1 plants, double flowers were observed owing to an increase in the number of petals (Fig. 1(C), (D)), and about 5% were observed to be dwarfs. For the dwarfs, the selling price decreased because of the smaller seedling size. In contrast, the rooting ability and heat resistance improved dramatically, and mutants with strong roots appeared. We confirmed that the M_2 plants inherited this strong root trait.

Thus, we have created a new Keika with strong roots viability. We aim to select plants that have double flowers, longer flowering period, strong roots viability, and high-temperature resistance from the Ar-ion irradiated group and commercialize them in the future.