Agronomic characteristics of new edible chrysanthemum cultivar 'Yamaen K4' induced by heavy-ion beam irradiation

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Boiled petals of chrysanthemum are a traditional food in Tohoku district and Niigata prefecture. The edible flower cultivars (Shokuyou-giku) were converted from ornamental cultivars with sweetness and a little bitterness. In recent times, edible chrysanthemum has been widely used as a color decoration in Japanese food. The edible petals of chrysanthemum are classified into purple petals and yellow petals. The former type is shipped in autumn as a seasonal product, while the latter is shipped nearly throughout the year. The amount of production of edible chrysanthemum in Yamagata prefecture is the largest in Japan. In Yamagata, edible chrysanthemum is successively shipped in combination with some other cultivars. However, the main yellow flower cultivar 'Kotobuki' shows a trend of reduction in shipment quantity and deterioration in quality due to the smaller flower size from late September. Thus, an increase in shipment quantity is required in the off-season month of October. Therefore, we developed new yellow edible chrysanthemum, 'Yamaen K4', harvested from the middle of October to the middle of November by mutation breeding using heavy-ion beam irradiation.

In 2006, petals of yellow flower cultivar 'Etenraku' (bred using somaclonal variation of 'Kotobuki' in Yamagata prefecture [1]) were picked and sterilized. Subsequently, petals were cut into approximately 1-cm squares and cultured on MS medium containing 5 mg/l BA and 5 mg/l NAA. Then, they were irradiated with a $^{12}C^{6+}$ ion beam (135 MeV/nucleon, LET 22.6 keV/μm) at 10 Gy at the RIKEN RI-beam factory. Irradiated samples had been incubated at 25°C in 68.9 μmol m^{-2} s^{-1} (PPFD) with 16 h day length for some time, and redifferentiated shoots were transplanted on an MS medium for plant elongation and rooting. Rooted plants were transferred to pots and acclimated to the outside air environment. In 2007, cutting seedlings made from 859 individual lines were planted into a greenhouse in November. These plants were evaluated during 2008-2011, and they had showed some mutation of the flowering period (Table 1), flower configuration, and other agronomic characteristics. Finally, one mutant line was selected in 2011. After it passed the field test, it was applied for seed and seedling registration in February 2015 and published for application in July as 'Yamaen K4'.

The flowering period of 'Yamaen K4' was from October to November and was different from that of the original cultivar, 'Etenraku', the flowering period of which is from July to September. The harvesting period was approximately 2-3 weeks from the middle ofOctober to the middle of November regardless of planting date and year (Table 2). Flower head diameters were approximately 80-90 mm in the early profit stage, and these values are slightly less than those of 'Etenraku'. However, the average flower head weight during the harvesting period is the same as that of 'Etenraku', and it depends on the small reduction in the flower head diameter of 'Yamaen K4'. The main color of the inner side of the ray floret is 7B or 7C (reference number of RHS Color Chart), that of the outer side is 7D or 8A, and all values are higher than the corresponding values for 'Etenraku' (Fig. 1, Table 3). The ray floret type is spatulate and incurved, and the ratio of the former type is greater than that for 'Etenraku'. The total number of ray florets in the flower head is the same as for 'Etenraku'. In 2010, the yield per stock was 2,429 g at the 7 May planting and 1,765 g at the 6 June planting, which indicate that the early planting yield tendency is as high as the late planting yield. However, planting before the beginning of June makes it difficult to harvest and control because the plant height increases beyond 110 cm. In 2011, it was easier to handle because the plant height was 86 cm in the case of planting at 27 June, and the yield per stock at that time was 1,569 g (Table 2). The tasting evaluation of 'Yamaen K4' was good and almost the same as for 'Etenraku' .

Table 1. Mutation of flowering date using heavy-ion beam irradiation

Amount of individuals (%)				
Early[z]	Equivalent[z]	Late[z]	Not yet flowering[y]	Total
5 (0.6)	218 (25.4)	477 (55.5)	159 (18.5)	859

z ; Early ; flowering 2 weeks before from original, Late ; flowering 2 weeks after from original, Equivalent ; other, y ; Containing decreased growth and dead individuals

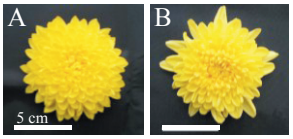

Fig. 1. Flower head of 'Yamaen K4' (A) and original cultivar 'Etenraku' (B)

Table 2. Characteristics of 'Yamaen K4' and standard cultivar (2011)

Planting date	Cultivar	Harvest date		Plant height (cm)[z]	Marketable yield per		Weight per Marketable flower head (g)
		Earliest	Latest		Number of flower head	Weight (g)	
6 Jun.	Yamaen K4	14 Oct.	14 Nov.	110	598	1,794	3.0
	Etenraku	12 Aug.	14 Nov.	56	413	1,188	2.9
	Kotobuki	29 Aug.	21 Nov.	88	640	1,593	2.5
16 Jun.	Yamaen K4	14 Oct.	14 Nov.	95	376	1,442	3.8
	Etenraku	12 Aug.	21 Nov.	50	367	1,132	3.1
	Kotobuki	12 Sep.	7 Nov.	89	573	1,589	2.8
27 Jun.	Yamaen K4	17 Oct.	14 Nov.	86	396	1,569	4.0
	Etenraku	1 Sep.	14 Nov.	47	188	597	3.2
	Kotobuki	26 Sep.	25 Oct.	77	361	1,116	3.1

z : Mean (n=5) , y : Mean in early stage of harvest period (n=30)

Table 3. Flower head morphology of 'Yamaen K4' and original cultivar (2013)

Cultivar	Flower head diameter (mm)[z]	Ray floret[z]		Number of disc floret[z]	Main color of ray floret[x]	
		Number	Type[y]		Inner	Outer
Yamaen K4	87	215	3,2	30	7C	7D
Etenraku	91	220	2,3	17	7D	5D

z : Mean in the early stage of harvest period (n=20), y : 1;ligulate, 2;incurved, 3;spatulate, 4;guilled, 5;funnel shaped, x : Reference number of RHS Color Chart (Japan garden plants standard color chart)

Reference

1) Hirono et al., Breed. Res. 1 (suppl. 2). **323**, (1999). (in Japanese)

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