ASPECT ON TRANSFER OF ECONOMIC CHARACTERS BY MEANS OF INTERSPECIFIC AND INTERGENERIC CROSSING IN CRUCIFEROUS CROPS

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The genera Brassica and Raphanus in Cruciferae are particularly important for their cultivated species which provide vegetables, oil-seed crops and forage crops. In Japanese oil-rape breeding, the interspecific hybridization between rape and turnip rape has been practically applied for about 50 years, and about 60% of registered rape cultivars have been bred through this method. But no one made clear the cytogenetic pathway of this method. The author has been engaged in cytogenetic and breeding studies of the interspecific and intergeneric hybridizations in Cruciferous crops, with special reference to transfer of economic characters such as disease resistance from B.oleracea to R.sativus, from B.oleracea or B.napus to B.campestris, and cold resistance and early maturity from B.campestris to B.napus through the application of sesquidiploids such as rrc(r'r c') - and aac(a'a c')-genomes plants.

For that purpose the author obtained five kinds of interspecific and intergeneric hybrids as follows: (1) amphihaploid ROF1 plants (2n=18,rc), obtained from the crosses between R.sativus (2n=18,rr,radish)and B.oleracea (2n=18,cc,cabbage,etc.), (2) sesquidiploid RROF1 plant (2n=27,rrc),obtained from the same crosses, (3) amphihaploid COF1 plants (2n=19,ac),obtained from the crosses between B.campestris (2n=20,aa,Chinese cabbage) and B.oleracea (2n=18,cc,cabbage, etc.), (4) sesquidiploid NCF1 or CNF1 plants (2n=29,aac), obtained from the crosses between B.napus (2n=38,aacc,rape, etc.) and B.campestris (2n=20,aa,turnip rape, Chinese cabbage,etc.), (5) sesquidiploid COOF1 plants (2n=28,acc), obtained from the crosses between B.campestris (2n=20,aa,turnip) and 4X-B.oleracea (2n=36,cccc,kohlrabi).

As shown in Fig.1 these interspecific and intergeneric hybrids could be classified into two groups based on the way of production of the sesquidiploid plants; group 1 --- in this case the sesquidiploid plants were obtained in the F1 generation as in the Fig. 1-c,-d and -e, group 2 --- in this case the sesquidiploid plants were obtained in the F2 generation as in the Fig. 1-a and -b.

Firstly, it appeared that the parent-like reversional plants such as Raphanus(radish)-like, campestris(Chinese cabbage, turnip rape and turnip)-like and napus(rape)-like, were segregated in the next generation from the sesquidiploid plants including hyper- and hypo-one. "Parent-like reversional plant" means the offspring which has the same number of somatic chromosomes as and a plant shape very similar to one of the parental species, and their genome constitution is presumed to be much the same as that of the parental species. Table 1 shows the frequency occurrence of the varied individuals in Raphanus-like and campestris-like reversional plants, obtained in the next generation from the sesquidiploid plants.

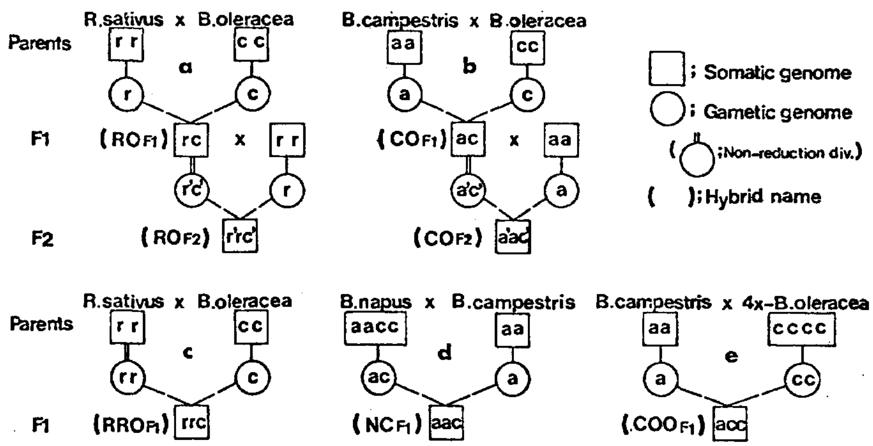

Fig.1. Schematic diagram of formation of the various kinds of the sesquidiploid plants.

TABLE 1

FREQUENCY OCCURRENCE OF VARIED INDIVIDUALS IN THE PARENTAL-LIKE REVERSIONAL PLANTS

Type of plants	Strain	Origin	Number of individuals observed	Number of varied individuals(%)	Number of healthy and vigorous individuals
Radish-like plant(2n=18)	ROF_3	amphihaploidF_1	188	79(42.0)	56
	$RROF_2$	sesquidiploidF_1	113	0(0.0)	0
Chinese cabbage-like or turnip-like plant (2n=20)	COF_3	amphihaploidF_1	13	3(23.1)	3
	NCF_2	sesquidiploidF_1	41	6(14.6)	0
	$COOF_2$	sesquidiploidF_1	2	2(100.0)	2

In the 2nd generation from the sesquidiploid RROF1 plant(2n=27,rrc), all of the 113 plants obtained by selfing, back-crossing with parental radish cultivar or open-pollination, were completely radish-like reversional plants that had no clear characteristic distinction from the parental radish cultivar. In the 2nd generations from NCF1(2n=29,aac) and COOF1(2n=28,acc) sesquidiploid plants, some campestris-like reversional plants were obtained by back-crossing with parental campestris cultivars or open-pollination, but no good promising campestris-like reversional plants appeared in the 2nd generation from the sesquidiploid F1 plants with the exception of COOF1 plants. However, some good promising campestris-like reversional plants might be segregated in the progenies from the campestris-like heteroploid F2 or F3 plants of the sesquidiploid NCF1 plants, especially in the case of the plant derived from the crossing between artificially synthesized napus crop and B.campestris. And some promising rape-like reversional plants were obtained in the progenies from NCF1 plants by successive back-crossing with parental napus cultivar. These rape-like reversional plants had both economic characters of disease resistance in B. napus and of cold resistance in B. campestris.

On the other hand, no reversional plants were segregated in the 2nd generation from the amphihaploid ROF1(2n=18,rc) and COF1(2n=19,ac) plants. Instead, the sesquidiploid plants including hyper- and hypo-ones were frequently obtained by back-crossing with the parental Raphanus or B.campestris cultivars or by open pollination. In the 3rd generation a lot of radish-like and chinese cabbage-like reversional plants were segregated by successive back-crossing or open pollination. In these cases, some shifts occurred in various characters from the original types of cultivars of radish and Chinese cabbage toward the oleracea type, and some promising reversional plants were obtained. Their resistance to virus and soft-lot diseases was stronger and they were very vigorous. Moreover, in the 4th generation the promising reversional plants were frequently segregated passing through the sesquidiploid F2 plants and radish-like or Chinese cabbage-like heteroploid F3 plants having some oleracea chromosomes. Therefore, it seems to be recognized that transfer of various economic characters from the species having c-genome into the species having r- or a-genome, occurs more frequently in the progenies of the amphihaploid F1 plants than in that of the sesquidiploid F1 plants.

Karpechenko (1924) and Fukushima (1929) reported that ROF1 plants(2n=18,rc) showed complete absence of chromosome pairing at metaphase-I of PMCs. But, the author observed some bivalent chromosomes, six being the maximum number, in my ROF1 plants. And a number of bivalent chromosomes were observed in COF1 (2n=19,ac) plants. The quite similar modes were ascertained in prior COF1 plants by U(1935), Feng(1955), Hosoda(1961) and Sarashima(1964, 1973). Table 2 shows the mean number of bi-, tri- and tetravalent chromosomes per cell in each ROF1 and COF1 strain. Therefore, it is assumed that more or less partial substitutions of chromosomes between r- or a-genome and c-genome plants must have taken place at the meiotic divisions in the amphihaploid plants and transfer of economic characters from the c-genome plants into the r- or a-genome plants must have occurred.

In the pollen-tetrad stage of the amphihaploid F1 plants, various kinds of sporads such as diads, triads, tetrads, pentads, etc. were usually observed. It could be considered that most of the viable gametes in the amphihaploid plants had to be the diploid gametes including hyper- and hypo-ones which arose from restitution nuclei. That is why a lot of sesquidiploid F2 plants appeared frequently in the 2nd generation of the amphihaploid F1 plants by back-crossing with parental mono-genomic species.

On the other hand, trivalent chromosomes were not frequently observed in the sesquidiploid plants with the exception of COOF1 plants (2n=28,acc), as will be seen in Table 3. Hence, only in the COOF1 plants partial substitutions of chromosomes between a- and c-genome plants had to have taken place at the meiotic divisions. Thus, many promising turnip-like reversional plants were obtained in the progenies from the COOF1 plants. And the author supposed that appearance of the promising rape-like reversional plants in the progenies from the NCF1 plants (2n=29,aac) had to be based on the partial substitutions of the chromosomes between a-genome in B. napus and that in B. campestris.

More or less viable mono-genomic and di-genomic gametes were produced in the sesquidiploid plants such as RROF1, NCF1, COOF1 and the derivative sesquidiploids from the amphihaploids such as ROF1 and COF1 plants. Therefore, mono-genomic or di-genomic reversional plants could be obtained in the next generation of various kinds of sesquidiploid plants including hyper- and hypo-ones.

An interesting conclusion from the author's experiments can be drawn: For the purpose of transfer of economic characters from one mono-genomic species into another, we ought first to produce a number of amphihaploid F1 plants and secondly ought to produce a number of derivative sesquidiploid F2 plants by back-crossing with one of the parental species to which we want to transfer useful economic characters. A number of varied parent-like reversional plants and parent-like heteroploids will then be obtained in the 3rd generation of the amphihaploid F1 plants. After that, the promising reversional plants will be frequently segregated in the progenies from the parent-like heteroploids by back-crossing or by successive mass-pollinations, and also in that from the parent-like reversional plants by successive mass-pollinations.

TABLE 2

MEAN NUMBER OF BI- AND MULTIVALENT CHROMOSOMES PER CELL AT METAPHASE-I IN EACH AMPHIHAPLOID ROF1(2n=18,rc) AND COF1(2n=19,ac) PLANT

	Genome and strain	Number of indiv. observed	Mean number of bi- and multivalent chromosomes per cell
rc	RO67F1	2	2.23 ± 0.16
	RO70IF1	4	1.07 ± 0.57
	RO70IIF1	7	0.18 ± 0.18
	RO70IIIF1	2	0.23 ± 0.32
	RO70IVF1	2	0.45 ± 0.49
	RO70VF1	14	1.23 ± 0.49
ac	COF1	2	3.06 ± 0.03

TABLE 3

MEAN NUMBER OF TRIVALENT CHROMOSOMES PER CELL AT METAPHASE-I IN EACH SESQUIDIPLOID F1 AND DERIVATIVE SESQUIDIPLOID F2 PLANT

	Genome and strain	Number of indiv. observed	Mean number of trivalent chromosomes per cell
rrc	ROF2	12	0.14 ± 0.19
	RROF2	1	0.07
aac	COF2	4	0.52 ± 0.40
	NCF1-A	25	0.35 ± 0.21
	NCF1-B	16	0.55 ± 0.23
acc	COOF1	13	2.02 ± 0.49