Cyto-genetic Studies On The Pomoideae : I. Chromosome Number Of The Cultivated Varieties Of Apples, European Pears, And Japanese Pears Cultivated In Japan

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https://doi.org/10.5109/22604

出版情報：九州大学大学院農学研究院紀要. 9 (1), pp.1-20, 1948-03. Kyushu University

Journal of the Faculty of Agriculture, Kyūshū University, Vol. 9, No. 1
March 31, 1948

CYTO-GENETIC STUDIES ON THE *POMOIDEAE*

I. CHROMOSOME NUMBER OF THE CULTIVATED VARIETIES OF APPLES, EUROPEAN PEARS, AND JAPANESE PEARS CULTIVATED IN JAPAN

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INTRODUCTION

Rybin (1926, 1927) had discovered, for the first time, the fact that two kinds of apple varieties, diploid, and triploid, were under cultivation in Russia, and thus had aroused a general interest towards the cytological investigation on the *Pomoideae*. His works had, no doubt, been undertaken to solve a problem of pollination, which was, and is now also, of much practical importance in fruit culture, especially to make clear the origin of inter-varietal differences on the pollen-producing ability. And soon, existence of the similar two kinds of European pears, *Pyrus communis* L., was made known by Kobel (1927). In 1930, Darlington and Moffett studied on the meiotic chromosomes of apples, and offered the following interesting hypothesis of the origin of the *Pomoideae*, on the basis of so-called "secondary association of chromosomes" and on the multivalent chromosome formation occurred in the meiotic metaphase; the diploid apple is no more of the primary genome constitution, and is probably a secondary polyploid species established through the secondary balance of chromosomes. Further, they insisted that the basic chromosome number 17, not only of apples or pears, but of all the species belonging to the subfamily *Pomoideae*, is not a primary basic number, and it should be rather considered as a secondary basic one. And thus a new development has been brought about on the cyto-genetic researches of the *Pomoideae*.

The hypothesis of "secondary association of chromosomes" was, in turn, applied extensively by Darlington and his colleagues with a number of plant species to make clear the remote origin of those species, which can not be disclosed by the data of actual chromosome pairing, and a fair number of papers of similar nature have been published since (Cf. Darlington, 1937). In this connexion, the works carried out on apples by Darlington and Moffett would be duely noticed as what provided a quite new general problem to cyto-genetics. The hypothesis of "secondary chromosome association," which presumes "secondary chromosome balance," however, seems to be not yet fully appreciated in general. There are not a few authors who doubt and stand against the hypothesis. And even though this cytological hypothesis could not be accepted as the working one, it is duely considered that the diploid species of *Pomoideae* may be something of the polyploid kind, according to the results of investigations carried out along the other ways of approach, such as the genetic analyses of heritable characters, the studies on the sterility and on the incompatibility phenomenon, and etc.

Surveys on the chromosome number of apples and of European pears have already been worked out to a certain extent. According to Heilborn (1935), there are 148 diploid varieties (2n=34) and 33 triploid ones (2n=51) in apples. With European pears, there are many reports, covering 61 diploid and 17 triploid varieties. Embryological studies were also carried out with some varieties, including some intensive ones with triploid apples (Cf. Elssman and v. Veh, 1932; Howlett, 1932; Steinegger, 1932; and v. Veh, 1933).

The author has engaged, since 1933, on the investigations on the chromosomes of apples, European pears, and Japanese pears (including a few Korean and Chinese varieties). In 1934, the author discovered two tetraploid varieties of Japanese pears, which is the only case of tetraploid forms hitherto reported on the cultivated ones in the *Pomoideae* (Ito and Fukushima, 1934). Some preliminary reports of the chromosome constitution of the apples and pears cultivated in Japan were already made (Ito and Fukushima, 1934, 1937, 1938; and Fukushima, 1937). Adati (1933, 1935), in Japan, also carried out investigations of chromosomes with a number of *Pyrus* forms, including the Japanese, European pear varieties and a few oriental wild forms.

MATERIAL AND METHOD

Apple materials were obtained from the experiment orchards of the former Central Experiment Station of Chôsen, Suigen, Korea, and of the University Farm, Fukuoka. European pear varieties were examined also on the trees cultivated in those orchards above stated, in addition to several varieties grown in the orchard of Prefectural Agricultural Experiment Station of Okayama. Materials of all the Japanese pears and of the hybrid seedlings raised between the Japanese and European pears were collected from the orchard of the University Farm. Names of all the varieties studied are listed in the following tables.

Flower buds were fixed doubly using Carnoy's and Flemming's weak fluids. Sections were cut by the ordinary paraffin method, and stained with Heidenhain's iron-alum haematoxylin.

Number of chromosomes was determined exclusively on the pollen mother-cells in meiotic metaphase.

OBSERVATIONS

Chromosome Numbers of Apples

Surveys on the chromosome number of apple varieties have been carried out rather extensively in Europe and in U.S.A. Works of Crane and Lawrence (1930), Darlington and Moffett (1930), Heilborn (1928, 1930, 1935), Kobel (1926, 1927, 1931), Miedzyrzecki (1933), Moffett (1931), Natividade (1932), Nebel (1929a, b, c, 1930), Roscoe (1933), Rybin (1926, 1927), and Shoemaker (1926) are mentioned. As stated above, there are two different kinds of varieties, diploid and triploid. Heilborn (1935) presented in his paper a list of 'varieties[1], compiled from the data hitherto

1) This list, Table 1 in Heilborn (1935), does not contain the Portuguese varieties reported by Natividade (1932).

obtained, including 148 diploid varieties along with 33 triploid ones[1].

Apple varieties now cultivated in Japan consist mainly of the strains introduced some eighty years ago, at the beginning of the Meiji era, from Europe and U.S.A., and of a few minor ones selected out of them. The author succeeded until now in determining the chomosome number with 34 varieties listed in the Table 1.

Table 1 shows that the nature of those 20 varieties out of 34 listed was determined by the author for the first time. There could not be found any one tetraploid variety in apples. Nebel (1929a, b, 1930) reported a form, "Kola", $2n=68\pm$, which was derived from a cross between an American crab-apple, "Elik River", and "Charlamowsky", and therefore it can not be well accepted as a true tetraploid variety under practical fruit culture.

Table. 1. *Apple varieties, of which chromosome constitution has been determined by the author.*

Variety[a]	Other authors[b]
Diploid variety, 2n=34	
1. Akin	
2. *Beni-iwai*	
3. *Beni-kokkô*	
4. *Beni-sakigaké* (Red Astrachan)	Nebel
5. *Beni-shibori* (Fameuse)	Nebel
6. Cooper's Early	
7. *Dai-kokkô* (Giant Geneton)	
8. Delicious	Nebel, Roscoe
9. Early Red Bird	Roscoe
10. Esopus Spitzenberg	Kobel
11. *Ezogoromo* (Roxbury Russet)	
12. Golden Delicious	
13. Golden Russet	Roscoe
14. *Hakuryû* (White Winter Pearmain)	
15. *Hatsu-hinodé* (Winesap)	Nebel
16. Henry Clay	
17. *Hô-ôran* (Yellow Bellflower)	Nebel, Rybin
18. *Indo*	
19. *Iwai* (American Summer Pearmain)	
20. *Ki-sakigakê* (Yellow Transparent)	Nebel

1) With 13 out of these 33 triploid varieties, chromosome count is not quite exact, but the estimation of its nature is considered to be highly probable.

21. *Kōgyoku* (Jonathan)	Nebel, Roscoe
22. *Kokkō* (Ralls)	
23. Lady's Apple	
24. *Mizuo* (Jersey Sweet)	
25. *Ryūgyoku* (Smith Cider)	
26. Stark	
27. *Suigyoku* (Newtown Pippin)	
28. *Tama-araré* (Grimes Golden)	Nebel, Roscoe
29. White Pippin	
30. *Yamato-nishiki* (Ben Davis)	Nebel
31. York Imperial	Nebel
Triploid variety, 2n=51	
32. Paragon	
33. *Sekiryū* (Baldwin)	Darlington & Moffett, Nebel, Kobel
34. Stayman Winesap[c]	

a. Japanese name of variety is written in italic type.
b. The variety followed by the names of other authors shows that the chromosome number was also determined by those authors.
c. Shoemaker (1926) also treated this variety as the one which may be of triploid in nature.

Chromosome Numbers of European Pears

As the chromosome surveys in European pears, *Pyrus communis* L., works of Florin (1927), Kobel (1926, 1927, 1931), Natividade (1932), Nebel (1930), Miedzyrzecki (1933), and Moffett (1934a, b) may be mentioned. Moffett (1934b) presented a list compiled from his own data, together with those of other workers, covering, in total, 41 diploid and 12 triploid varieties, 3 of which were somewhat uncertain. In addition to those varieties listed above, Nebel (1930) has reported 8 diploid, Florin (1927) 1 triploid, and Natividade (1932) 12 diploid and 3 triploid varieties, and thus the diploid varieties are amounting to 61 and triploid to 16 in total. As in apples there is not any one tetraploid variety. Cultivation of European pears in Japan started also by the early introduction of the strains from Europe and U.S.A., along with apple strains mentioned above. In Japan, there had been carried out only Adati's (1935) investigation upon four varieties.

The author determined the chromosome number with all the varieties listed in the following Table 2, which includes 40 diploid and 5 triploid ones, amounting 45 in total.

Chromosome Numbers of Japanese Pears

Preliminary reports of the chromosome surveys on the Japanese pears were made by the author in 1934. Japanese pears belong to *Pyrus serotina* Rehder, which is indigenous to Japan proper, the Central and South China regions, composing one of the large groups of the oriental pears. The author's survey covered mostly those pears of Japanese origin, including several so-called Korean pears, which are considered to be of similer origin, and two varieties of North China pear, *Pyrus ussuriensis* Maxim.[1]

Table 2. *European pears, of which chromosome constitution has been determined by the author.*

Variety	Other authors[a]
Diploid variety, 2n=34	
1. Alexandrine Douillard	
2. Aspasie Aucourt	
3. Bartlett	Kobel, Moffett, Adati
4. Bergamotte Espéran	
5. Beurré Clairgeau	Moffett
6. Beurré d'Anjou	Nebel
7. Beurré d'Avril	
8. Beurré Dubuisson	
9. Beurré Hardy	Kobel, Moffett
10. Beurré Sterckmans	
11. Buffum	
12. Charles Ernest	Miedzyrzecki
13. Citron des Carmes	
14. Clapp Favorite	Miedzyrzecki
15. Conférence	Moffett
16. Dr. Jules Guyot	Moffett, Miedzyrzecki
17. Doyenné d'Alençon	
18. Doyenné du Comice	Kobel, Moffett
19. Doyenné d'Angoulême	
20. Easter Beurré	
21. Flemish Beauty	Nebel
22. Fondante d'Automme	
23. Fondante Thirriot	Kobel

1) According to Kikuchi (1944), pears indigenous to North China region comprise of two distinctive subgroups of *Pyrus ussuriensis* Maxim., i.e., var. *culta* Kikuchi and var. *sinensis* Kikuchi. Two North China varieties treated in this paper belong to the latter form. Socalled Chinese pears are considered to have been mostly composed of the two major forms, *P. serotina* Rehd. and *P. ussuriensis* Maxim.

24.	Glou Morceau (from Suigen)	Kobel, Moffett
25.	Idaho	
26.	Illinois Lincoln	
27.	La France	Adati, Natividade
28.	Lawrence	
29.	Le Lectier	Natividade
30.	Lincoln	
31.	Marguerite Marillat	Moffett
32.	Michaelmas Nelis	
33.	Oriental	
34.	Passe Crassane	Moffett, Miedzyrzecki
35.	Sheldon	
36.	Souvenir du Congrès	
37.	Suzette de Babay	
38.	Triomphe de Vienne	Miedzyrzecki
39.	White Doyenné	
40.	Winter Nelis	Nebel
Triploid variety, 2n=51		
41.	Glou Morceau (from Okayama)[b]	
42.	Pitmaston Duchess	Moffett
43.	Pound	
44.	Spina di Carpi	
45.	Triomphe de Jodoigne	Natividade

a. See note in Table 1.
b. This variety is doubtful, may be a misinterpreted "Triomphe de Jodoigne."

On the previous paper, the author reported 55 diploid varieties, 2 tetraploids (2n=68), and no triploid at all, and further, from his results of studies on 24 F_1 seedlings between *P. communis* and *P. serotina*, he made clear the fact that each F_1 seedling has, without exception, 34 chromosomes in diploid state. Also Adati (1935) carried out chromosome survey with 28 varieties as mentioned below. Varieties treated by the author until now are presented in the following Table 3, covering 61 varieties in total.

Table 3 shows that 41 out of 61 varieties were newly determined by the author. Diploid and tetraploid varieties are distinguished among Japanese pears, no triploid one being met with.

Crosses between *P. communis* and *P. serotina* succeed rather easily, producing F_1 viable seedlings. Actually, there are several cultivated forms which are duely accepted to have been established through such a process.[1] The author examined 24 such seedlings, including 15 different cross-combinations, raised for the breeding materials at his laboratory, disclosing that all the F_1 seedlings were diploid in chromosome constitution. Table 4 shows the reults of such studies.

Table 3. *Japanese pears, of which chromosome constitution has been determined by the author.*

Variety [a]	Other author [b]
Diploid variety, 2n = [illegible]	
A. Japanese races	
1. *Abumi*	
2. *Asahi*	
3. *Atago*	
4. *Azuma-nishiki*	
5. *Banroku*	
6. *Doitsu*	Adati
7. *Fuji*	
8. *Gion*	
9. *Gyokusui*	Adati
10. *Hakata-ao*	Adati
11. *Hakuteiryû*	
12. *Hatsushimo*	
13. *Hinomaru*	
14. *Imamura-aki*	Adati
15. *Imamura-natsu*	
16. *Ishii-wasê*	
17. *Ichihara-wasê*	Adati
18. *Kikusui*	Adati
19. *Kinchaku*	
20. *Kôno-watashi*	Adati
21. *Kôzô*	Adati
22. *Kubo-nashi*	
23. *Kunitomi*	
24. *Kyokuryû*	
25. *Matsushima*	
26. *Meigetsu*	Adati
27. *Niitaka*	
28. *Nijisseiki*	Adati
29. *Ôhiromaru*	Adati

1) "Kieffer", "Le Conte", and etc., are well considered to have originated through such hybridizations, so they are mentioned as *Eurasian* varieties by some workers.

30.	*Ôku-sankichi*	Adati
31.	*Okwan*	
32.	*Rokugatsu*	
33.	*Sagami*	
34.	*Seiryû*	
35.	*Seiryû* (of Kikuchi)	
36.	*Segawa*	
37.	*Sekai-ichi*	Adati
38.	*Sekiryû*	Adati
39.	*Shihyakumê*	
40.	*Shikishima*	Adati
41.	*Shingetsu*	
42.	*Shintyû*	Adati
43.	*Taihaku*	Adati
44.	*Taihei*	Adati
45.	*Tamagawa*	
46.	*Tenyû*	
47.	*Tosa-nishiki* [c]	Adati
48.	*Tyôzyûrô*	Adati
49.	*Wase-aka*	Adati
50.	*Wase-tyôzyûrô*	
51.	*Yakumo*	
52.	*Yawata-nishiki*	
53.	*Yenoshima*	
B. Korean races		
54.	Kankori	
55.	Seidôro	
56.	Shinmuri	
57.	Tyon-sari	
C. Chinese pears (*P. ussuriensis* Maxim.)		
58.	Ya Li	Adati
59.	Tsu Li	
Tetraploid variety, 2n=68		
60.	*Shin-tyôzyûrô*	
61.	*Tosa-nishiki*	

a. and b. See notes in Table 1.
c. The author observed two different strains, diploid and tetraploid, under this varietal name. Relationship between these two strains has not yet been made clear.

Table 4. *List of F_1 hybrid seedlings between European and Japanese pear varieties, of which chromosome constitution has been determined by the author.*

Expt. Notation	Parental combination[a]			2n
1. 17-2	(C) Louise Bonne de Jersey	×	(S) *Sekiryû* (34)	34
2. 33-1	(S) *Sekiryû* (34)	×	(C) Brown Beurré	34
3. 57-3	(C) Émile d'Heyst	×	(S) *Sekiryû* (34)	34
4. 75-1	(C) Roosevelt	×	(S) ,,	34
5. 75-3	(C) ,,	×	(S) ,,	34
6. 123	(C) Duchesse d'Angoulême (34)	×	(S) *Oku-sankichi* (34)	34
7. 136-1	(C) Émile d'Heyst	×	(S) ,,	34
8. 156-1	(C) Souvenir de Zules Quandon	×	(S) ,,	34
9. 156-2	(C) ,,	×	(S) ,,	34
10. 156-3	(C) ,,	×	(S) ,,	34
11. 156-4	(C) ,,	×	(S) ,,	34
12. 171	(C) La France (34)	×	(S) ,,	34
13. 178-3	(C) ,,	×	(S) ,,	34
14. 236-1	(C) Brown Beurré	×	(S) *Nijisseiki* (34)	34
15. 192	(C) White Doyenné (34)	×	(S) *Sekiryû* (34)	34
16. 217-1	(S) *Tyôzyûrô* (34)	×	(C) Duchesse d'Angoulême (34)	34
17. 217-4	(S) ,,	×	(C) ,,	34
18. 238-2	(S) *Nijisseiki* (34)	×	(C) Brown Beurré	34
19. 235	(S) ,,	×	(C) ,,	34
20. 266-1	(C) Louise Bonne de Jersey	×	(S) *Nijisseiki* (34)	34
21. 279-1	(S) *Nijisseiki* (34)	×	(C) Émile d'Heyst	34
22. 279-2	(S) ,,	×	(C) ,,	34
23. 285	(S) ,,	×	(C) Andre Desportes	34
24. 468-1	Not identified			34

a. Parental variety followed by (34) shows that its somatic number of chromosomes was determined by the author, and thus the chromosome constitution of those varieties not followed by this notation was not yet determined. (C) and (S) are the abbreviations of *P. communis* and *P. serotina* respectively.

REMARKS

A polyploid series of diploid (2n=34), triploid (2n=51), and tetraploid (2n=68) was clearly demonstrated throughout the cultivated varieties of apples, European pears and Japanese pears. And the fact that those polyploid forms are of autopolyploid in nature was also made known by the author, but the results of his observations was not treated in this report. According to the surveys hitherto worked out on the apple varieties, 34 (16.9%) out of 201 determined were autotriploid, and the rest 169 diploid (See Appendix I). With the European pears, 90 varieties out of 111 were diploid and the rest 21 (18.9%) autotriploid (See Appendix II). And both of the apple and pear species did not contain any one autotetraploid variety, while of 67 Japanese pear varieties and 2 North China ones examined there appeared 2 autotetraploid ones, and all the rest were exclusively diploid. Thus there could not be noticed any one autotriploid variety in Japanese pears (See Appendix III). Such rather marvellous circumstances may have probably been derived from the fact that the mode of evolution of Japanese pears was somewhat different from that of the European pears or of apples. For instance, it may be considered that the breeding processes through the sexual reproduction did not play an important rôle in the establishment of Japanese pears. But this perhaps may not be the true situation. For the production of triploid seedlings, the diploid gametes must be formed by any means, so the occurrence of such abnormal gametes may be considered to have been much more frequent in *Malus communis* or in *Pyrus communis* than in *P. serotina*. It is supposed that there might be some adverse conditions which prevented the varietal differentiation in Japanese pears through the triploid individuals occurred by the above process or by some other ways. In my laboratory, a large number of F_1 seedlings, which have been raised through the crosses between tetraploid and diploid pears, have already been under cultivation, so that the investigations with these individuals will suffice to solve the questions presented above. Since the crosses between apples and European or Japanese pears always resulted in failure, not obtaining any one F_1 seedling, we can not make clear the genomic interrelationship between *Malus* and *Pyrus*. But the crosses between two pear species are more or less successful, and the author himself also succeeded in obtaining a fair number of such hybrid seedlings. From the studies on the meiotic behaviours of chromosomes of the hybrid individuals the author made known that these two genomes concerned are quite similar in homology, not showing any great differences on their differentiation.[1] Therefore the two species, *P. communis* and *P. serotina*, are duely considered to belong to the same form.

Wild ancestral forms of the cultivated species and several wild species of *Malus* and *Pyrus*, which are supposed to have participated in the formation of the cultivated forms, are exclusively diploid in chromosome constitution, not including any one polyploid form.

Actual mechanisms which produced autopolyploidy in the cultivated apples and pears have not yet been clearly demonstrated. The author, however, once tried to apply a high temperature on the flower-buds of some Japanese pear varieties, during a certain period of meiosis, and succeeded in obtaining diploid or tetraploid pollen-grains together with the normal haploid ones.[2] Spontaneous occurrence of such polyploid gametes through a similar process may not be unprobable even under the natural conditions. According to Nebel (1936), however, even one triploid pear variety newly raised has not yet been reported, during recent about sixty years, from the breeding stations of all over the world, and he himself also could not find out any one triploid seedling out of ca. 5,000 seedlings raised by the crosses among diploid varieties at Geneva Station. And thus Nebel insisted that the possibility of obtaining triploid individuals among the offsprings of the diploid varieties may be very little if any.

With both the apples and European pears, it is well known that the matings such as triploid × triploid, or triploid × diploid and its reciprocal, are more or less successful, resulting in some F_1 seedlings. Because of the chromosome unbalance, almost all the seedlings thus produced show very weak growth, not coming

1) The results of the author's investigations will be published in a following paper of this series in near future.

2) With those flowers the author carried out, further, the self-pollination, and the cross-matings with other pollens from various sources, and the seedlings thus raised are now under cultivation.

up to the fruitful trees, and therefore the utilization of such aneuploid seedlings for the breeding purposes is considered to be of little promise (Cf. Nebel, 1933, 1936). The author carried out, since 1933, crosses between tetraploid and diploid Japanese pears, succeeding rather easily in raising a number of F_1 seedlings, of which chromosome constitution may be triploid or its close approximate. From these seedlings, the production of triploid varieties with practical usefulness seems quite probable to the author.[1)]

Heilborn (1935) reported that many triploid apples have a high keeping quality than the diploid ones, and as accepted somewhat generally, he attributed this relation to the more or less slow metabolic or other physiologic activities of the individual cell composing the autopolyploid organisms. Some other workers stated also that the above features of the individual cell may have no less significant bearings on the various other characteristics of practical value, such as early or late maturing of the woody tissues, relating to the hardiness of the variety, contents of vitamin C or other essential materials in fruits, pollination or fruit-setting procedures, and etc. But the exact status is not yet taken as what fully elucidated. If we can succeed in obtaining artificially a large number of polyploid strains, especially those of tetraploid apples or pears, then we can develop a quite new progress on the practical breeding of the *Pomoideae* upon the utilization of polyploidy.

The author wishes to acknowledge his obligations to Prof. H. Ito for his suggestions and advices, and to Mr. T. Hosomi, who has done a part of the routine work.

SUMMARY

Chromosome constitutions were determined, at meiosis of the pollen mother-cells, on a large member of the varieties in *Pomoideae* cultivated in Japan as follows; 34 varieties of apples (*Malus communis* L.), 45 of European pears (*Pyrus communis* L.), 59 of Japanese pears, including 4 Korean pears (*P. serotina* Rehd.), and 2 of

1) The author has under cultivation a large number of such hybrid individuals together with a number of tetraploid F_1 seedlings raised between two tetraploid varieties.

North China pears (*P. ussuriensis* Maxim.). Three apples and 5 European pears were triploid (2n=51), and 2 Japanese pears were tetraploid (2n=68). And all the other varieties examined were exclusively diploid (2n=34). The author, further, examined 24 hybrid F_1 seedlings obtained from 15 different cross-combinations between European and Japanese pears, and made clear that all these seedlings had exclusively 34 chromosomes in diploid state.

A few considerations were made on the origin of non-occurrence of triploid varieties in Japanese pears, and on the mechanisms relating to the formation of polyploid varieties in general. And further, from various important characters duely ascribed in the polyploidy itself, a promising development on the practical breeding of the *Pomoideae* was suggested by the artificial raising of polyploid individuals.

In the appending three lists the varieties, chromosome constitutions of which have hitherto been determined are presented.

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APPENDIX

Chromosome Constitutions of the Cultivated Pomoideae.

I

APPLES

Variety [a]	Authority [b]	Variety	Authority
	DIPLOID VARIETY, $2n=34$		
Aderslebener Calville	N	Calville Lesans	N, Mi
Akerö	H	Calville rouge	Mi
Akin	F	Candille Sinap	R
Alexander	H	Carlisle Pippin	C & L
Allington Pippin	C&L, D&M	Cellini	H, K
American Summer Pearmain (*Iwai*)	F	Charlamovsky (Duchess of Oldenburg)	H, N, Ro
Annie Elizabeth	C & L		
Antonovka	R	Cooper's Early	F
Antonovka-Kamenitchka	R	Cox's Orange Pippin	C&L, D&M, K
Apfel aus Lunow	N		
Aport	R	Cox's Pomona	D & M, H
Astrachan, Big Transparent	H	Danziger Kantapfel	K
Astrachan, Red (*Beni-sakigakê*)	N, F	Dash-Alma	R
Astrachan, White	H, K, R	Deacon Jones	Ro
Babushkino	R	Delicious	F, N, Ro
Barlovskoje	R	Djir Hadzhi	R
Baumanns Reinette	M, K	Dolgo	N
Beauty of Bath	C&L, D&M	Duchess Favourite	D & M
Belle Fille	Mi	Early Red Bird	F, Ro
Belleflower, Yellow (*Hôoran*)	R, N, F	Early Victoria	C&L, D&M
Belleflower × Kitaika (Mitshurin)	R	Eden	N
Belle Joséphine	Mi	Eneroth's Klaräpple	H
Belyi Naliv	R	Esopus Spitzenberg	K, F
Ben Davis (*Yamato-nishiki*)	N, F	Fameuse (*Beni-sibori*)	N, F
Beni-iwai	F	Fenouillet jaune	Mi
Beni-kokkô	F	Fenouillet rouge	Mi
Berner Rosenapfel	K	Géante des Expositions	Mi
Blanche d'Espagne (Kalmar-glasäpple)	Mi	Geheimerat Dr. Oldenburg	N
Böhmer (Der)	N	Gelber Richard	N, H
Borowinka-Borowitsky	Mi	General von Hammerstein	N
Calville blanc	Mi	Giant Geneton (*Dai-kokkô*)	F
Calville du Roi	R	Golden Reinette of Kursk	R
Calville Grand Duke of Baden	N	Golden Russet	F, Ro

a. Japanese names of variety are presented in italic types.

b. Names of authors are indicated in the abbreviated characters as follows; A, Adati; C & L, Crane and Lawrence; D & M, Darlington and Moffett; F. Fukushima; H, Heilborn; K, Kobel; M, Moffett; Mi, Miedzyrzecki; N, Nebel; Na, Natividade; R, Rybin; and Ro, Roscoe.

Goldparmaene	Mi
Grenadier	C & L
Grimes Golden (*Tama-araré*)	N, Ro, F
Gragylling	H
Gule-Penbe	R
Halland's Brunnsäpple	H
Hampus	H
Henry Clay	F
Indo	F
Irish Peach	C & L, D & M
Jersey Sweet (*Mizuo*)	F
Jonathan (*Kôgyoku*)	N, Ro, F
Kasseler Reinette	K
Kavlas	H
Kentish Codlin	C & L,
Keswick Codlin	C & L, D & M
Lady's Apple	F
Lane's Prince Albert	N, C & L, D & M
Lord Derby	C & L
Lord Grosvenor	R
Macoun	N
Maglemer	H
Mank's Codln	C & L, N
Mann	Ro
Margaretaäpple, red	H
McIntosh	N
Medina	N
Melba	N
Melon	H
Milton	N
Minister von Hammerstein	N
Muskata-Reinette	K
Newfane	N
Newton Wonder	C & L
Newtown Pippin (*Suigyoku*)	F
Northern Spy	C & L, D & M
Oland's Kungsäpple	H
Ontario-Reinette	K, N
Opalescent	Ro
Oranie	H
Oslins	C & L
Patte d'Oie	Mi
Pearmain d'Adam	Mi
Pfirsichroter Sommerapfel	K
P.J. Bergius	H
Ralls (*Kokkô*)	F
Rambour de Himbsel	Mi
Rambour of Tsarkoje Selo	R
Red Spy	Ro
Reine des Reinettes	Mi
Reinette de Champagne	R
Reinette d'Oberdieck	R
Reinette d'Orléans	R
Reinette pain de Sucre	Mi
Reinette rouge d'Hiver	Ro
Reinette très tardive	Mi
Reinette Zuccamaglio	C & L
Rev. W. Wilks	M
Rival	C & L
Rolfe (Macomber)	Ro
Rome	N
Rosenhäger	H
Rosmarin blanc	R
Roter Jungfernapfel	N
Roter Stettiner	R
Roxbury Russet (*Ezogoromo*)	F
Sary-Sinap	R
Sary-tursh-Alma	R
Sävstaholm	H
Signe Tillisch	H
Skvoznoy Naliv	R
Smith Cider (*Ryûgyoku*)	F
Sommergewürzapfel	K
Sommerrambour	N
Stätblühender Taffetapfel	N
Stäringe	H
Stark	F
Stenkvrka	H
Suislepper	R
Sutton	N
Svanetorp	H
Tchernoguz	R
Tchulanovka	R
Titovka	R
Transparente blanche	H
Transparente de Cron el	K, H
Twenty Ounce	N
Vaughan Seedless	N
Vitgylling	H
Wagner	Ro
Wealthy	H, N
Weidner's Goldreinette	N
Wellington	N, Ro
White Pippin	F
White Winter Pearmain (*Hakuryû*)	F

Winesap (*Hatsu-hinodé*)	N, F	Worcester Pearmain	C & L, D & M
Winter Banana	Ro	Yellow Newtown	N
Winter Golden Pearmain	R	Yellow Transparent (*Ki-sakigaké*)	N, F
Winter Gray Reinette	R	York Imperial	Ro, F
Winter Majetin	C & L	Zelenka Crimean	R
Wolf River	Ro		

TRIPLOID VARIETY, 2n=51

Arkansas	N	Jaques Lebel	K
Baldwin (*Sekiryû*)	D & M, N, K, F	Menznauer Jägerapfel*	K
Blenheim Orange	C & L, D & M, K, N	Nonpareil	Ro
		110 Nomblott (Margille ?)	Mi
Bohnapfel*	K	Paragon	F
Bramley's Seedling	C & L, D & M	Reinette grise de Vitry	Mi
Canadian Reinette	R	Reseda-Reinette*	K
Crimson Bramley	D & M	Rhode Island Greening	N
Damason-Reinette*	K	Ribston Pippon	C&L, N, H, K
Fallawater	Ro	Rossvik*	H
Fall Pippin	N	Roter Eiserapfel*	K
Frösaker	H	Schöner von Boskoop	N, K
Genet Moyle	C & L	Stäfner Rosenapfel*	K
Gravensteiner, and its mutations	N, K, H, Ro	Stark	Ro
		Stayman Winesap	F
Harbert's Reinette*	K	Tompkin's King	N
Holland Pippin	N	Warner's King*	K
Hurlbut*	H	Washington	M
Husmodersäpple*	H	Winter-Zitronenapfel*	K

II

EUROPEAN PEARS

DIPLOID VARIETY, 2n=34

Alexandrine Douillard	F	Beurré de Naghin	Mi
André Desportes	K	Beurré Dubuisson	F
Aspasie Aucourt	F	Beurré Dumont	Mi
Baronne de Mello	M	Beurré Fougeray	M
Belle des Abrès	Mi	Beurré Giffard	Mi, M
Bergamotte Espéran	F	Beurré Hardy	K, M, F
Beurré Bosc	M, N	Beurré Six	M
Beurré Clairgeau	M, F	Beurré Sterckmans	F
Beurré d'Anjou	N, F	Beurré Superfin	M
Beurré d'Avril	F	Bon Chrétien d'Hiver	Mi
Beurré de Mortillet	M	Charles Ernest	M, F

* Chromosome constitution is not quite certain.

Charles Marchal	Mi
Chalk	M
Citron des Carmes	F
Clapp's Favourite	Mi, F
Comtesse de Paris	M
Conference	M, F
Dr. Jules Guyot	Mi, M, F
Doyenné d'Alençon	F
Doyenné du Comice	K, M, F
Duchesse d'Angoulême	F
Durondeau	M
Easter Beurré	F
Fertility	M
Flemish Beauty	N, F
Fondante Thirriot	K, F
Frühe von Trévoux	K
Gansel Bergamot	M
Gayuga	N
Glou Morceau	K, M, F
Gorham	N
Herzogin Elsa	M
Himmelfahrtsbirne	Na
Idaho	F
Illinois Lincoln	F
Kieffer	N, A
La France	Na, A, F
Lawrence	F
Lebrunn's Butterbirne	K
Le Conte	A
Le Lectier	N, F
Lincoln	F
Louise Bonne de Jersey	K
Marguerite Marillat	M, F
Marie Louise	M
Marques Loreiro	Na
Michaelmas Nelis	F
Napoleon	M
Neue Poiteau	K
Olivier de Serres	Mi
Orange Bergamot	M
Oriental	F
Passe Crassane	Mi, M, F
Rei	Na
St. Luke	M
Seckel	N
Sheldon	F
Souvenir du Congrés	Mi, F
Suzette de Babay	F
Triomphe de Vienne	Mi, F
Tyson	N
Van Mons	Na
White Doyenne	F
William's Bon Chretien (Bartlett)	K, M, [illegible]
	A, F
Winter Nelis	N, P

TRIPLOID VARIETY, $2n=51$

Alexander Lucas	Florin
Bärikerbirne	K
Beurré d'Amanlis	M, K
Beurré Diel	Mi, M, K
Catillaç	M
Conseiller à la Cour (Hofratsbirne)	M, K
Doyenné Bussoch	M
Leitao	Na
Pitmaston Duchess	M, F
Pound	F
Rateau Gris	Mi
Sete Cotovelos	Na
Schweizer Wasserbirne[*]	K
Spina di Carpi	F
Theilersbirne[*]	K
Triomphe de Jodoigne	Na, F
Uvedale's St. Germain	M
Vicar of Winkfield (Pastorenbirne)	Na, K

[*] Chromosome constitution in not quite certain.

III

Japanese Pears

DIPLOID VARIETY, 2n=34

(A) Japanese races	
Abumi	F
Amanokawa	A
Akappo	A
Asahi	F
Atago	F
Azuma-nishiki	F
Banroku	F
Doitsu	A, F
Fuji	F
Gion	F
Gyokusui	A, F
Hakata-ao	A, F
Hakuteiryû	F
Hatsushimo	F
Hinomaru	F
Imamura-aki	A, F
Imamura-natsu	F
Ishii-wasé	F
Ichihara-wasé	A, F
Kikusui	A, F
Kintyaku	F
Kô-no-watashi	A, F
Kôzô	A, F
Kubo-nashi	A, F
Kunitomi	F
Kyokuryû	F
Matsushima	F
Meigetsu	A, F
Niitaka	F
Nijisseiki	A, F
Ôhiromaru	A, F
Oku-sankichi	A, F
Okwan	F
Rokugatsu	F
Sagami	F
Seiryû	F
Seiryû (of Kikuchi)	F
Segawa	F
Sekai-ichi	A, F
Sekiryû	A, F
Shihyakumé	A, F
Shikishima	F
Shingetsu	F
Shintyu	A, F
Taihaku	A, F
Taihei	A, F
Tamagawa	F
Tenyû	F
Tosa-nishiki	A, F
Tyôzyûrô	A, F
Uebana	A
Wasé-aka	A, F
Wasé-Tyôzyûrô	F
Yakumo	F
Yatiyo	A
Yawata-nishiki	F
Yenoshima	F
(B) Korean races	
Kankori	F
Seidôro	F
Shinmuri	F
Tyon-sari	F
(C) North China pears (*P. ussuriensis* Maxim.)	
Tsu Li	F
Yah Li	A, F

TETRAPLOID VARIETY, 2n=68

Shin-Tyôzyûrô	F
To a-nishiki	F