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Polyploidy breeding in fruit crops

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Abstract
Polyploidy is a phenomenon, which is formed from meiotic aberrations related to spindle fibre formation. It is mainly of two types *i.e.* euploidy and aneuploidy. It may occur naturally or can be induced by artificial means. Polyploidy breeding is an important tool for widening variability in fruit crops with narrow genetic base like banana. It has really wide implications in obtaining bigger fruit size and disease resistant plant types. However, sterility has been seen as a general problem in most of such cases, which has to be taken care of before commercialization of polyploids.

Keywords: Polyploidy, autopolyploid, allopolyploid, chromosome, spindle fibre

Introduction
Polyploids are organisms with multiple sets of chromosomes in excess of the diploid number. Polyploidy is common in nature and provides a major mechanism for adaptation and speciation. Approximately 50-70% of angiosperms, which include many crop plants, have undergone polyploidy during their evolutionary process. The phenomenon of polyploidy, or the existence in genetically related types of chromosome numbers which are multiples of each other, is one of the most widespread and distinctive features of the higher plants and was one of the earliest of their cytogenetic characteristics to become extensively studied and well understood. The artificial production by Winkler (1916) of a tetraploid form of *Solanum nigmm* through decapitation and the regeneration of callus tissue was perhaps the first example of the direct production in a laboratory experiment of a new, constant genetic type.
The number of chromosomes either increases or decreases in a basic set of chromosomes during the process of polyploidy. If there is 2 set of chromosomes usually present inside the cell, a new set of chromosome can be added due to non-disjunction of chromosome resulting formation of polyploidy. Polyploid is an individual with more than two identical or distinct genomes. Polyploidy is produced by multiplication of a single genome (autopolyploid) or combination of two or more divergent genomes (allopolyploid) (Chen and Ni, 2006) [4]. Polyploidy breeding refers to induced chromosome manipulation.

Different ploidy levels
The polyploid species are of two types

1. Autopolyploid species/individual
A situation arises inside the cell due to cell nondisjunction during the cell division it means if nondisjunction occurs between same species, it will be called autopolyploid. Normally autopolyploid occurs due to the mitosis nondisjunction.
Autopolyploid contains more than two copies of a single genome.

2. Allopolyploid species/individual
Allopolyploidy is a situation or the increment of chromosome number in set occurs due to the fuse of 2 different cells of 2 different species. It means if nondisjunction occurs between different species it will be called allopolyploids.

Origin and production of autopolyploids
1. Spontaneous: Spontaneously polyploids can be produced but at a low frequency due to meiotic irregularities, formation of unreduced gametes or sometimes chromosome doubling occurs in somatic tissues.
2. Due to treatment with physical agents: By heat or cold treatments, centrifugation, irradiations like x-ray or gamma ray.

3. Regeneration *in vitro:* Plants regenerated from cells and suspension cultures may be polyploids
4. Colchicine treatment: In the late 1930s it was discovered by that colchicine inhibits the formation of spindle fibers and temporarily arrests mitosis at the anaphase stage (Blakeslee, 1937) [2] leads to a polyploid cell. Colchicine extracted from the seeds or corms of autumn crocus (*Colchicum autumnale*)

Plant material used for treatment-

1. Diseases free material
2. Meristematic tissues with the region
3. Leaf buds / Scions/ Cuttings /Seeds
4. Aseptic cultures of shoot tips, bud tip meristems, embryos and single cell.
5. Other chemical agents: Acenaphthene, 8-Hydroxyquinoline, Nitrous Oxide can also be used for induction of polyploidy in plants.

Formation of autopolyploids

Whenever normal meiosis is not happening than diploid gametes directly pass through progeny so offspring will be tetraploid instead of diploid.

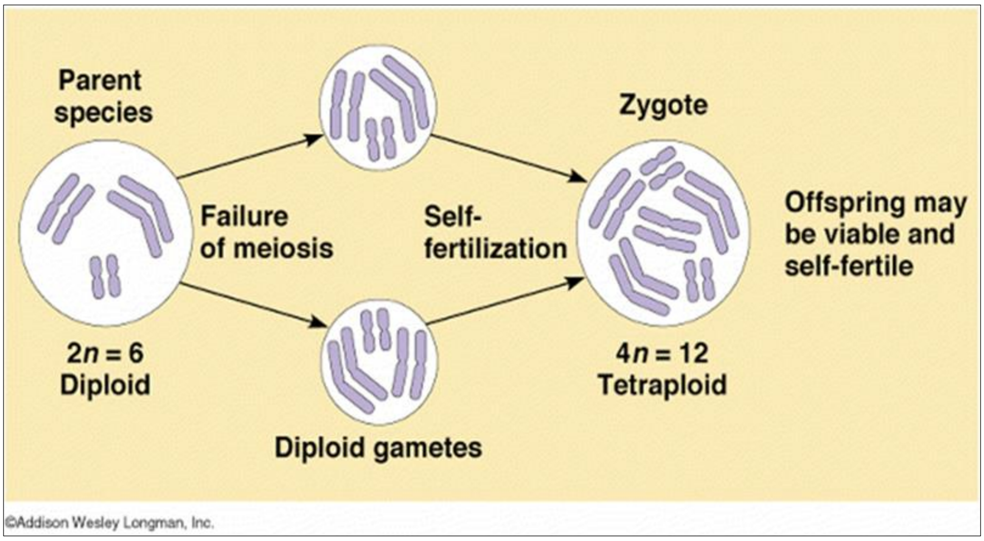

Fig 1: Formation of autopolyploids

Formation of allopolyploids

1. Protoplast fusion to produce allopolyploids.
2. Crossing two species with unreduced gametes

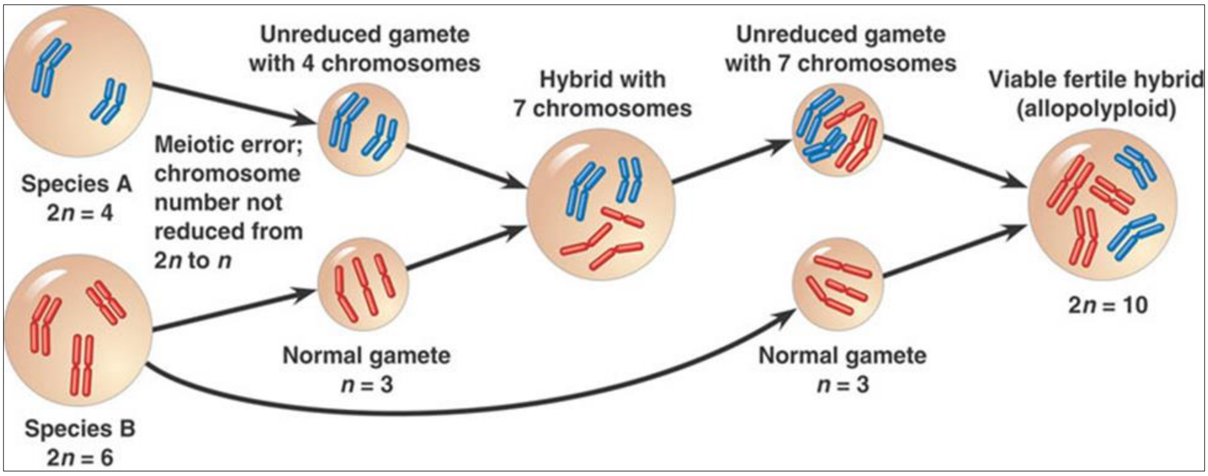

Fig 2: Formation of allopolyploids

Protoplast fusion has been used to produce novel allotetraploid hybrids for use as parents in crosses with diploids to produce triploid plants. Protoplast fusion technology has been utilized in many crops to generate allotetraploid somatic hybrids, and sometimes autotetraploids as a by-product of the process. Protoplast fusion has become a significant tool in ploidy manipulation that can be applied in various cultivar improvement schemes. In rare cases, a new somatic hybrid may have direct utility as an improved cultivar; however, the most important application of somatic hybridization is the building of novel germplasm as a source of elite breeding parents for various types of conventional crosses for both scion and rootstock improvement. Somatic hybridization is generating superior allotetraploid breeding parents for use in interploid crosses to generate seedless triploids; several thousand triploid hybrids have been produced using somatic hybrids as the tetraploid parent. Protoplast fusion is also being utilized to produce somatic hybrids that combine complementary diploid rootstocks, which have shown good potential for tree size control. Tree size control has gained importance as a means of reducing harvesting costs, maximizing the efficiency of modern cold protection methodology, and facilitating the adaptation of new fruit production systems. This technique can facilitate conventional breeding, gene transfer, and cultivar development by bypassing some problems associated with conventional sexual hybridization including sexual incompatibility, nucellar embryogenesis, and male or female sterility (Grosser and Gmitter 1990) [7]. Applications of somatic hybridization in crop improvement are constantly evolving, and original experiments generally targeted gene transfer from wild accessions to cultivated selections that were either difficult or impossible to accomplish by conventional methods (Grosser *et al.*, 1996) [8].

Characters of polyploids
1. Leaves are large in size
2. Thicker and stouter stem
3. Precocity is delayed (juvenile phase is long)
4. Polyploid plants exhibit disease resistance
5. Fruit size are bigger
6. More intense colour of leaf and fruit

Applications of autopolyploids in crop improvement
Triploids
4x X 2x. highly sterile. This feature is useful in the production of seedless citrus fruits.

Tetraploids
(1) Breeding, (2) improving quality, (3) overcoming self-incompatibility, (4) making distant crosses (5) used directly as varieties
1. In banana, autotetraploids are produced by chance fertilization of an unreduced triploid egg (AAA) by haploid pollen from a disease resistant diploid parent and used in incorporating disease resistance to commercially successful varieties.
2. As bridging species
3. Production of new crop species,
4. For widening the genetic base of existing allopolyploid crop species. Overcoming barriers to hybridization
5. Developing sterile triploid cultivars
6. To make S.I plants fertile
7. Enhancing pest resistance and stress tolerance
8. Better fruit Quality
9. Eg: Fruit from octaploid stawberry twice as large as diploid fruit

Achievements and potential in fruits
Apple
- Development of Triploid Cultivars is desirable as triploid forms and cultivars are characterized by more regular fruit-bearing, more marketable fruit of larger size, higher autogamy and scab resistance. (Sedov E. N., 2013) [13]
- At the All Russian Research Institute of Fruit Crop Breeding the apple breeding on a polyploidy level has been carried out since 1970.
- 4x x 2x and 2x x 4x: Most promising types of crossings for breeding triploid seedling.
- Salt stress tolerance: observed in autotetraploid plants of ‘Hanfu’ and ‘Gala’ induced by colchicine treatment. (Xue *et al*., 2015) [27]
- Drought stress tolerance: observed in autotetraploids developed by Xue *et al*. (2015) [27].

Banana
- Majority of cultivated varieties are triploid and sterile except Gross Michel which produces unreduced gametes. Unfortunately Gross Michel is susceptible to Fusarium and its tetraploid hybrid retains this character.
- So, colchicine induced autotetraploids (disease resistant) can be crossed with superior diploids to yield desirable triploid cultivar. (Hamill *et al*., 1992) [4]
- CARBAP and CIRAD used colchicine for chromosome-doubling of diploid stocks and for their further hybridization with diploid stocks to obtain triploid hybrids (Escalant and Jain, 2004) [6]

Citrus
- Excessive number of seeds in citrus makes it unappealing to the consumers
- Seedlessness has been successfully achieved through ploidy manipulations as triploidy is associated with sterility
- 3x: spontaneous, 2x crosses, endosperm culture, somatic hybridization (2x+1x), 4x × 2x crosses (Esen and Soost, 1972).
- The interploidal hybridization (4x × 2x), most effective and is commonly used to produce seedless triploids. However tetraploids in nature is limited so
- Induction of Polyploidy by colchicine has been performed in *Citrus reticulata* (Elyazid *et al*., 2014) [5], pummelo (Kainth and Grosser, 2010) [14].
- Protoplast fusion used to produce novel allotetraploid hybrids for use as parents. *i.e*. allotetraploid hybrids of Encore mandarin and Valencia sweet orange produced by protoplast fusion for seedless triploid citrus breeding (Wu *et al*., 2005) [25].

Rootstock breeding
- In Florida smaller trees are desirable.
- Tetraploid citrus rootstocks have shown the ability to reduce tree size.
- Somatic hybrids such as sour orange + rangpur lime or sour orange + Palestine sweet lime, can yield over 22 tons (20,000 kg) fruit per acre, have better soil adaptation than Flying Dragon, which does not perform well on high pH, calcareous soils (Grossser and Gmitter, 2011) [3].
- Tetraploid citrus rootstocks are more tolerant to salt stress than are diploid plants. (Saleh *et al.,* 2008).

Grapes
- Big berry size is a desirable character so tetraploidy is induced.
- ‘Wanheibao’: A new polyploid (4x) late season table grape with muscat flavor was released in china. It is the result of hybridization between ‘Guibao’ and ‘Qiuhong’ and harvested seeds were treated with colchicine (Tang *et al*., 2015) [15].
- ‘Shenfeng’, a new tetraploid hybrid of table grape (Jiang *et al*., 2007) [6].

Ber
- In 2009 ‘Chenguang’, a new tetraploid Chinese jujube cultivar induced by colchicine on the stem apex of the diploid ‘Linyilizao’ was released in China. (Ping *et al*., 2012) [10]
- Bigger fruits and better fruit quality

Pear

- Natural triploid: Beurré Diel, Beurré d' Amanlis', Catillac' and Pitmaston Duchess.
- 'Merton Pride' were deliberately produced by 2*x* x 4x cross.
- Polyploid pear cultivars have larger organs and good quality especially triploid pear. (Huang *et al*., 1990) [5]
- Pear have gametophytic S.I, so Kadota and Niimi (2002) [13] developed tetraploid plants from a diploid cultivar Hosui, to obtain self-compatible plants for use as mother plants or pollen parents to produce triploid plants by crossing.
- Cao *et al.*, 2001 [3] studied efficiency of hybridized combination of ploidy for pear polyploid breeding and found 4x×4x is the best combination type for tetraploid breeding and 4x×2x is the ideal combination type for triploid breeding.

Pineapple

- Manipulation of ploidy in pineapple was first explored in the PRI program, Hawaii in the 1940.
- 4x: vigorous but produced poor quality fruit
- 3x: good quality, large size fruit
- 4x of elite cultivars crossed 2x, would produce triploid progeny very similar to the tetraploid parent with only a few traits inherited from the diploid (Sanewski *et al*., 2011) [19]
- The 'Gigante de Tarauacá' is a native pineapple of Northern Brazil. that produces large fruits (as much as 15 kg) and is a natural triploid. (Scherer *et al*., 2015) [12]

Kiwi

- Traditional cross breeding is difficult due to differences in the ploidy level of species (Jin-Hu Wu, 2012) [26].
- *A. eriantha* is diploid, *A. chinensis* cultivars are either diploid or tetraploid, *A. arguta* cultivars are tetraploid. *A.* deliciosa cultivars are hexaploid
- Ploidy manipulation is considered as a promising method to circumvent the problems caused by this variation in ploidy (Beatson *et al*., 2006; Wu *et al*. 2011) [6, 26].
- Wu *et al*., in 2012 [16] reported that, autotetraploids 50–60% larger than fruit of their diploid progenitors 'Hort 16A'.

Guava

Autopolyploidy

Seedless varieties found it to be autotriploid.

- Kumar and Ranade (1952) [7]
- Majumder and Singh (1964) [9]

Aneuploidy

- Seedless triploid crossed with seeded diploid variety Allahabad Safeda (IARI).
- Sharma (1982) [14] identified a promising dwarf rootstock aneuploid No. 82 (tetrasomic) and was released as Pusa Srijan in 2004 at IARI, New Delhi

Conclusion

Polyploidy can be utilized to develop varieties in fruit crops, which have a narrow genetic base. It will facilitate in development of drought and salt stress tolerant fruit varieties and also insect and disease resistance. Since, no direct genetic manipulation is involved, the varieties developed will be acceptable and welcomed by the masses.

References

1. Beatson RA, Datson PM, Harris-Virgin PM, Graham LT. Progress in the breeding of novel interspecific *Actinidia* hybrids. In: VI International Symposium on Kiwifruit. 2006; 753:147-153.
2. Blakeslee AF, Avery AG. Methods of inducing doubling of chromosomes in plants: by treatment with colchicine. Journal of Heredity, 1937; 28(12):393-411.
3. Cao Y, Huang L, Li S, Yang Y. Genetics of ploidy and hybridized combination types for polyploid breeding in pear. In: International Symposium on Asian Pears, Commemorating the 100th Anniversary of Nijisseiki Pear. 2001; 587:207-210.
4. Chen ZJ, Ni Z. Mechanisms of genomic rearrangements and gene expression changes in plant polyploids. Bioessays. 2006; 28(3):240-252.
5. Elyazid DMA, El-Shereif AR. *In vitro* induction of polyploidy in *Citrus reticulata* Blanco. American Journal of Plant Sciences, 2014; 5(11):1679.
6. Escalant JV, Jain SM. Banana improvement with cellular and molecular biology, and induced mutations: Future and perspectives. 2004.
7. Grosser JW, Gmitter Jr FG. Protoplast fusion and citrus improvement. Plant Breed Rev, 1990; 8:339-374.
8. Grosser JW, Mourao-Fo FAA. Gmitter FG, Louzada ES, Jiang J, Baergen K *et al*. Allotetraploid hybrids between Citrus and seven related genera produced by somatic hybridization. Theoretical and applied genetics, 1996; 92(5):577-582.
9. Grosser JW, Gmitter FG. Protoplast fusion for production of tetraploids and triploids: applications for scion and rootstock breeding in citrus. Plant Cell, Tissue and Organ Culture. 2011; 104(3):343-357.
10. Hamill SD, Smith MK, Dodd WA. *In vitro* induction of banana auto-tetraploids by colchicine treatment of micro propagated diploids. Australian Journal of Botany. 1992; 40(6):887-896.
11. Huang Lisen, Shuling Li, Cong Peihua. Characteristic comparison of polyploid and diploid varieties of pear. China Fruits. 1990; 45:30-31.
12. Jiang AL, Li SC, Yang TY, Jin PF, Luo J. A New Tetraploid Grape Cultivar 'Shenfeng'. Acta Horticulturae Sinica. 2007; 34:1063.
13. Kadota M, Niimi Y. *In vitro* induction of tetraploid plants from a diploid Japanese pear cultivar (*Pyrus pyrifolia* N. cv. Hosui). Plant Cell Reports. 2002; 21(3):282-286.
14. Kainth D, Grosser JW. Induction of autotetraploids in pummelo (*Citrus grandis* L. Osbeck) through colchicine treatment of meristematically active seeds in vitro. In Proceedings of the Florida State Horticultural Society. 2010; 123:44-48.
15. Kumar LSS, Ranade SG. Autotriploidy in guava (*Psidium guajava* Linn.). Current Science. 1952; 21:75-76.
16. Majumder PK, Mukherjee SK. Aneuploidy in Guava (*Psidium guajava* L.). Cytologia. 1972; 37(4):541-548.
17. Majumder PK, Singh RN. Seedlessness in guava (*Psidium guajava* L). Current science. 1964; 33(1):24.
18. Ping L, Li D, Mengjun L, Hong'en J, Zhihui Z, Jiurui W *et al.* Chenguang, A new tetraploid Chinese jujube cultivar. Fruits. 2012; 67(4):293-296.
19. Sanewski GM, Smith MK, Pepper PM, Giles JE. Review of Genetic Improvement of Pineapple. In VII International Pineapple Symposium. 2011; 902**:**95-108.

20. Scherer RF, Olkoski D, Souza FVD, Nodari RO, Guerra MP. Gigante de Tarauacá: a triploid pineapple from Brazilian Amazonia. Scientia Horticulturae. 2015; 181:1-3.
21. Sedov EN. Results and prospects in apple breeding. Universal Journal of Plant Science. 2013; 1(3):55-65.
22. Sharma YK. Rootstock investigation in guava (*Psidium guajava* L.) Doctoral dissertation, Thesis submitted for the award of Ph.D. degree to Meerut University, Meerut, 1982.
23. Tang XP, Chen J, Ma XH, Dong ZG, Zhao QF, Li XM *et al.* 'Wanheibao': A new polyploid late-season table grape with muscat flavor. VITIS-Journal of Grapevine Research. 2015; 54(1):47-48.
24. Wu JH. Manipulation of ploidy for kiwifruit breeding and the study of *Actinidia* genomics. Acta Horticulturae. 2012; 961:539-546.
25. Wu JH, Ferguson AR, Mooney PA. Allotetraploid hybrids produced by protoplast fusion for seedless triploid Citrus breeding. Euphytica, 2005; 141(3):229-235.
26. Wu JH, Ferguson AR, Murray BG. Manipulation of ploidy for kiwifruit breeding: in vitro chromosome doubling in diploid *Actinidia chinensis* Planch. Plant Cell, Tissue and Organ Culture (PCTOC). 2011; 106(3):503-511.
27. Xue H, Zhang F, Zhang ZH, Fu JF, Wang F. Zhang B *et al*. Differences in salt tolerance between diploid and autotetraploid apple seedlings exposed to salt stress. Scientia Horticulturae. 2015; 190:24-30.