

## Polyploidy Breeding in Agriculture

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### *Abstract*

Polyploid is a condition where the chromosomes are more than complete sets. The chromosome sets can vary owing to both natural and man-made processes. In artificial process, the mostly used chemical is colchicine which is a toxic alkaloid extracted from *Colchicum autumnale* which was first discovered in 1937. Polyploids help to increase the size of the cells i.e., gigas. Despite being a technique for creating variance, it is not becoming more popular. This research examines several facets of polyploidy breeding by examining various published works. They outperform natural diploids in terms of high yield, resilience to biotic and abiotic factors, and having better vigor. Irregular fruits, higher percentage of water, sterility made the polyploidy application concentrated only to vegetatively propagated and seedless plants. Although using polyploidy in breeding programs is not a novel method, it is continuously being investigated for potential improvements.

**Keywords:** Chromosome, Colchicine, Genes, Meiosis

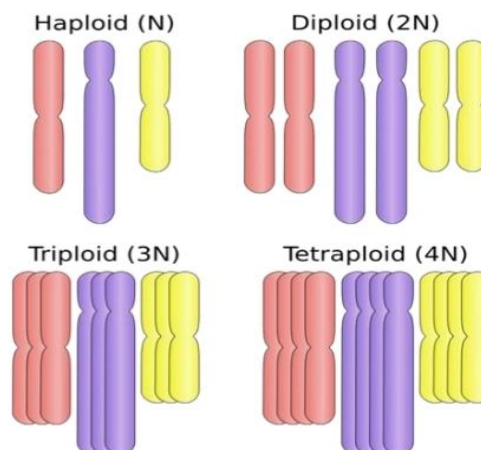
### INTRODUCTION

An organism with more than the complete set of chromosomes is called polyploidy organism denoted by "x". Where poly means many and ploidy means the complete set of chromosomes normally seen on plant species but rare in the case of animals. Polyploids differ from diploids in some morphological and physiological characteristics. Different forms of ploidy level can be written as diploid with two sets of chromosomes (2x), triploid with three sets of chromosomes (3x), tetraploid (4x), pentaploid (5x), and so on. The normal condition of ploidy level is diploids. The main effect of polyploidy is an increase in cell mass and loss in fertility. Based on development, ploidy is subdivided into two – Naturally induced ploidy and Artificially Induced ploidy. To develop polyploidy plants governing these three characteristics are preferred: crops with low chromosome numbers, known for vegetative parts, and cross-pollinating. Different crops are naturally polyploids like potatoes (Tetraploids), Wheat, and oats (hexaploids). Inducing doubling natural polyploids have

detrimental effects. There is a threshold level from which there will not be any beneficial impacts. Though it is not a new breeding method, in the present context the applicability and practical use of polyploidy are being discussed worldwide. This paper will discuss how the ploidy level is changed and its impacts on agriculture.

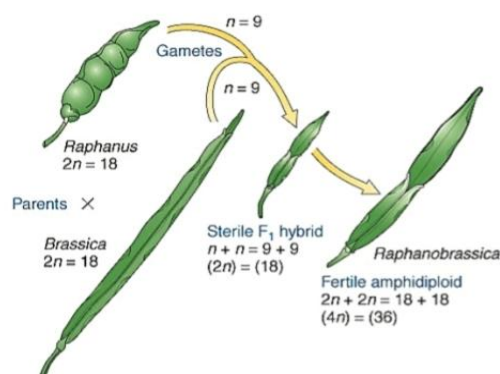
## METHODOLOGY

The review paper addresses the different aspects of polyploidy breeding, including its history, accomplishments, and downsides. It is based on a survey of several literature related to polyploidy breeding. This article takes use of recently available knowledge and facts. In order to learn more about the unique issues and potential for polyploidy breeding to develop diversity in the future, these considerations were taken into account in the review



**A) Chromosomal Structure of Haploid and Polyploids**

| Table 1: History Related to Polyploidy |                                                                                                                                             |
|----------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| Date                                   | Event                                                                                                                                       |
| 1882                                   | Chromosome was first discovered by Walther Flemming                                                                                         |
| 1888                                   | W. Rimpao derived Triticale from the cross between Wheat and Rye.                                                                           |
| 1916                                   | Termed Polyploidy by Winkler                                                                                                                |
| 1917                                   | Hypothesis on "Occasional Hybridization produces Doubling of Chromosome" by Winge                                                           |
| 1927                                   | <i>Rhaphanobrassica</i> ( $4x=36$ ) from <i>Raphanus sativus</i> ( $2x=18$ ) and <i>Brassica oleracea</i> ( $2x=18$ ) By G. D. Karpenchenko |
| 1930's                                 | Discovery of mitotic Inhibitors                                                                                                             |
| 1937                                   | Treatment of Colchicine was found to produce doubling of chromosome by Blakeslee <sup>1</sup> (Pal and Ramanujam, 1939).                    |



**Breeding program of Rhaphanobrassica**

## AUTOPOLYPLOIDY VS ALLOPOLYPLOIDY

The doubling of the chromosome is known as polyploidy. Which are subdivided into two parts based on the source for doubling.

| AUTOPOLYPLOIDY                                |                    | ALLOPOLYPLOIDY                           |
|-----------------------------------------------|--------------------|------------------------------------------|
| Doubling of chromosomes from the same species | <b>Definition</b>  | Doubling of Genes from different species |
| Homologous                                    | <b>Chromosomes</b> | Heterogenous                             |
| Mating of the same species                    | <b>Mating</b>      | Due to the mating of different species   |
| Doesn't undergo meiosis                       | <b>Meiosis</b>     | Undergo meiosis process                  |
| Oats, Potato, Sugarcane                       | <b>Example</b>     | Wheat and Animals                        |

## APPLICATIONS OF POLYPLOIDY

The main effect of polyploidy on plants is that they increase the size of the plant parts, increase vigor, and more resistance power to biotic and abiotic factors in comparison to the diploid plants. Some of the applications of polyploidy in the agriculture world are summarized below. Seedless Watermelon Seedless watermelon (3X) was first developed in 1939 by Kihara and Nishiyama by treated with Colchicine (Andrus, 1971). The shoot apex treatment with colchicine was found most effective (Whener, 2008)

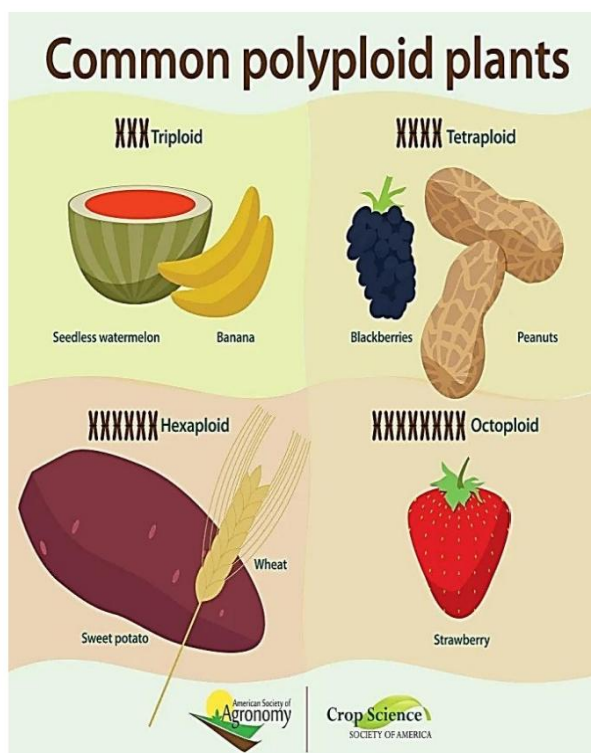
**TRITICALE:** In 1875, Hybrids between wheat and rye were first reported by Wilson. Artificially created Triticale was developed from the cross between wheat (3X,4X) and rye (3X,4X) consisting of chromosomes from both parents. It is of octoploid triticales (8x) and hexaploid triticales (6x) (Zillinsky, 1974).

**POLYPLOIDY ZINGER:** Zingiber officinale Rosc. (2X=22) chromosomes were doubled to develop polyploid Zinger (4X=44). Tetraploids differ from diploids in their leaf length thickness and width and Stem diameter. In tetraploid, the concentration of carotenoids was 1.35 times that of diploid plants, and yield increased up to 0.90 times (Zhou et al., 2020; Kunhua et al., 2011).

**TETRAPLOID BANANA:** Tetraploid banana is best based on the market point of view. Tetraploid banana is produced by double diploids, crossing diploids, and triploids. They are found to be resistant to Panama wilt disease, Sigatoka disease, etc. (Stover and Buddenhagen, 1986).

**CHRYSANTHEMUM:** Diploid chrysanthemum contains  $2x=18$  chromosomes, when they are doubled using colchicine treatment tetraploid varieties are developed which are superior in flower size, color purity, stem size, and chemical

**GRAPES:** Naturally present diploids (2X,  $2n=36$ ) were used to produce tetraploids (4x,  $2n=72$ ), Hexaploids (6X,  $2n=108$ ), and Octaploids (8X,  $2n=144$ ) by using colchicine treatment. Tetraploids were superior to others in terms of yield, grape size (1.2-1.5 times than diploids), root system, and stability over generations. Hexaploids were good in the root system but the yield



was not superior whereas octaploids were inferior (Notsuka et al., 2000).

**RICE**: First of all, two indica-japonica species of rice were crossed, and the progenies were collected. Then they were crossed with Polyploid meiosis stability (PMs) genes to develop polyploid rice (Detian et al., 2006). Tetraploid Rice was less susceptible to Salt tolerance in comparison to diploid rice.

## **NEGATIVE POINTS OF POLYPLOIDY**

### **6.1 Size of the Cell**

Due to an increase in cell size, some of the plants were found inferior. The shape of the fruits, and stems was irregular.

### **6.2 Infertility**

Sexually propagated polyploid plants were found to be producing infertile seeds. In some cases, it was fixed by crossing tetraploids with diploids to produce triploids that experimented to produce high levels of fertile seeds. In auto polyploids, sterility is observed due to the formation of polyvalent during meiosis. In the case of allopolyploids, they are derived from the

hybridization of interspecific species. Thus, they produce a sterile hybrid but by chromosomal doubling, fertility is obtained (Levy and Feldman, 2014). Tetraploid red clover is in limited use due to poor seed production.

### **6.3 Multi Doubling**

There would be no improvement in doubling the naturally present polyploids. It experimented on *Solanum tuberosum* which is naturally hexaploidy. Doubling of chromosomes resulted in small tuber size, and less vigor than natural.

## **CONCLUSION**

Although polyploidy breeding is not a new strategy in breeding programs, it is still being researched for various mechanisms that might make it more effective. All of this allowed for the artificial development of polyploidy thanks to colchicine therapy. However, this study focuses on the successes and drawbacks of polyploidy breeding. Future research has numerous chances to address the drawbacks by creating novel polyploid breeding techniques and by analyzing the genetics of polyploid species and their effects in various ecological and environmental contexts.

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