

## NARRATIVE REVIEW: THE ROLE OF GENETIC ENGINEERING AND DNA REPLICATION IN THE FORMATION OF SUPERIOR SHALLOT VARIETIES

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<p><b>Info Article</b></p> <p>Received : 01 Oktober 2025</p> <p>Revised : 02 November 2025</p> <p>Accepted : 02 Desember 2025</p> <p>Publication : 30 Desember 2025</p> <p><b>Keywords:</b> Genetic Engineering, DNA Replication, Colchicine, Polyploidy, Red Onion Seeds</p> <p><b>Kata Kunci:</b> Rekayasa Genetika, Replikasi DNA, Kolkisin, Poliploidi, Biji bawang merah</p> <p><i>Licensed Under a Creative Commons Attribution 4.0 International License</i></p> 	<p><b>Abstract:</b> <i>Shallots are an important horticultural commodity in Indonesia, but their productivity remains low due to limited superior varieties, high susceptibility to disease, and decreased vigor resulting from the continuous use of bulbs as seeds.. This study aims to assess the effectiveness of polyploidy induction and the role of DNA replication in the formation of superior onion varieties through a literature review of three major journals. The method used was a literature study by searching for articles related to genetic engineering, in vitro culture, the use of colchicine, and changes in plant phenotypes through the PubMed, ScienceDirect, and Google Scholar databases. The results showed that colchicine can inhibit spindle fiber formation during cell division, thereby promoting DNA replication without chromosome separation and producing polyploid plants with larger cells and organs. The application of colchicine in in vitro culture, meristem, and True Shallot Seed (TSS) has been proven to increase bulb size, improve morphological characteristics, and increase plant vigor. In addition, TSS offers advantages such as longer storage life, pathogen-free, and more uniform growth.</i></p> <p><b>Abstrak:</b> Bawang merah merupakan komoditas hortikultura penting di Indonesia, namun produktivitasnya masih rendah akibat terbatasnya varietas unggul, mudah terserang penyakit, dan menurunnya vigor akibat penggunaan umbi secara terus-menerus sebagai benih. Penelitian ini bertujuan untuk menilai efektivitas induksi poliploidi dan peran replikasi DNA dalam pembentukan varietas bawang unggul melalui tinjauan pustaka pada tiga jurnal utama. Metode yang digunakan adalah studi literatur dengan mencari artikel terkait rekayasa genetika, kultur in vitro, penggunaan kolkisin, dan perubahan fenotipe tanaman melalui basis data PubMed, ScienceDirect, dan Google Scholar. Hasil kajian menunjukkan bahwa kolkisin dapat menghambat pembentukan serabut spindel selama pembelahan sel, sehingga mendorong replikasi DNA tanpa pemisahan kromosom dan menghasilkan tanaman poliploid dengan sel dan organ lebih besar. Penerapan kolkisin pada kultur in vitro, meristem, dan Benih Bawang Asli (True Shallot Seed/TSS) terbukti meningkatkan ukuran umbi, memperbaiki karakter morfologi, dan meningkatkan vigor tanaman. Selain itu, TSS memiliki keunggulan seperti umur simpan lebih lama, bebas patogen, dan pertumbuhan lebih seragam.</p>
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## INTRODUCTION

Shallots (*Allium ascalonicum* L.) are a horticultural commodity that plays an important role in meeting the food needs of the Indonesian people. In addition to being used as a staple ingredient in almost all Indonesian dishes, shallots also have strategic economic value because they contribute to the stability of national food prices. The increasing demand is not always production has shown an upward trend in recent years, its distribution is uneven and most regions still experience a deficit. This challenge is exacerbated by the limited number of superior local shallot varieties, which generally have relatively small bulbs, are susceptible to disease, and experience a decline in vigor due to the continuous use of bulbs as seeds.

Genetic engineering is one approach that has the potential to address these challenges. Through chromosome manipulation and intervention in genetic processes, this technique enables the creation of superior traits that are difficult to achieve through conventional breeding. One widely researched method is the induction of polyploidy using colchicine, which works by inhibiting spindle formation during cell division. Disruption of this process causes DNA replication to occur without chromosome separation, resulting in cells with higher ploidy levels. This process of DNA replication without chromosome separation forms the basis for polyploidy, which is a plant with a doubled number of chromosomes that usually exhibits larger cell size, thicker leaves, and the potential for increased bulb size. The three journals reviewed show that colchicine treatment in *in vitro* cultures, meristems, and True Shallot Seeds (TSS) can trigger chromosomal changes that are relevant to the development of superior varieties.

DNA is genetic material that stores all the hereditary information of an organism. DNA has the ability to replicate, that is, to duplicate itself before the cell undergoes division. The DNA replication process is very important because it ensures that each daughter cell obtains a copy of the genetic information that is the same as its parent cell (Yulianti, 2024). DNA replication and gene regulation are two fundamental processes in biochemistry that are essential for the functioning and maintenance of all living organisms. DNA replication is the process by which DNA is copied or duplicated prior to cell division, enabling the inheritance of genetic information from one generation to the next. This process is important for growth, development, and cell repair in multicellular organisms and is strictly regulated to ensure fidelity and accuracy (Rooney T., 2023).

Colchicine is a compound used in plant breeding to induce polyploidization by disrupting cell division. Research shows that polyploidization with colchicine in onions can increase bulb size and alter morphological and physiological traits. Generally, colchicine is effective at concentrations of 0.01-1% (Safira et al., 2024).

Efforts to improve onion varieties through conventional breeding face various obstacles, particularly limited genetic diversity and high levels of pest attacks. Therefore, genetic engineering and chromosome manipulation technologies are becoming increasingly relevant approaches to enhance the genetic potential of onions. One widely used method is the induction of polyploidy through the application of colchicine. This technique can double the number of chromosomes, resulting in polyploid plants with larger cell and organ sizes. Various studies show that polyploid shallot plants have the potential to produce larger bulbs and better growth. In addition, research on the use of True Shallot Seed (TSS) as planting material opens up new opportunities because TSS has a longer shelf life, is more disease-free, and produces more uniform plant growth compared to bulbs.

Polyploidy is a condition in which plant cells undergo chromosome doubling, resulting in a chromosome set that is more than twice the normal number. This change not only affects cell size but can also alter the genetic ratios that play a role in regulating growth and tissue differentiation. As a result, polyploid plants often exhibit noticeable morphological changes, such as larger leaves and stems, increased tissue thickness, and the potential for larger tubers or fruits. In addition, polyploidy also often increases plant resistance to pests, diseases, and environmental stress due to the high content of genetic material that allows for more diverse and stable gene expression. Thus, polyploidy is an important approach in genetic engineering to produce superior and adaptive plant varieties. Mutations are changes in the genetic material (genes or chromosomes) of a cell that are passed on to its offspring. Mutations can be caused by errors in the replication of genetic material during cell division by radiation, chemicals (mutagens), or viruses, or they can occur during meiosis. However, there are also mutations whose mutagens are unclear, which are thought to be due to an oversight or error in a metabolic process in the cell. This occurs because of probability, not because of external influences, but simply by chance (Khairani et al., 2024). Increasing shallot production can be done by applying plant breeding techniques or methods as an effort to improve plant genetics, such as obtaining new shallot varieties that are superior to

previous varieties. These methods are also used to improve plant characteristics, especially yield and production characteristics.

**METHOD**

This research is a literature review that examines studies on DNA replication and the application of genetic engineering in shallots. The scope includes articles discussing DNA replication mechanisms related to ploidy changes, chromosome induction techniques using colchicine, and phenotypic and cytological changes due to genetic engineering. Literature was collected through searches of scientific databases such as PubMed, Scopus, and Google Scholar using relevant keywords, then selected based on topic relevance and data completeness. The operational variables examined included induction methods, treatment concentration and duration, DNA replication or ploidy level indicators, and plant morphological responses. The analysis was conducted descriptively by comparing findings between studies, then synthesized to assess the role of DNA replication and genetic engineering in the formation of superior onion varieties (Fitri *et al.* 2025).

**RESULTS AND DISCUSSION**

**Results**

Table 1. Comparison of Red Onion Polyploidy Induction Studies Using Colchicine

No	Author & Year	Object/ Variety	Colchicine Concentration and Method	Main Results	Biological Effects (DNA Replication and Genetics)
1	Husain <i>et al.</i> (2022)	Red onion variety	0-0.5% (Bulb soaking)	Does not affect plant height; increases the number of tillers & leaves; increases abnormal plants at high doses	Polyploidization occurs due to chromosome segregation failure after DNA replication, increasing phenotypic diversity
2	Wardani & Damanhuri (2024)	Red onion TSS Senren variety (in vitro)	0.25-1% for 24-48 hours	Optimal concentration 0.75% (24 hours), resulting in pentaploid, increased root growth and plant height	In vitro exposure enhances the effect of colchicine on meristem cells, with normal DNA replication but failed mitosis leading to polyploidy
3	Safira <i>et al.</i> , (2024)	Red onion variety Bima Brebes	1600-6400 ppm (0.16- 0.64%)	Polyploidization acts as classical genetic engineering to increase cell size & bulb productivity	Stable polyploidy formed at medium doses, changes in stomatal size indicated an increase in DNA copies in cells

Source: (Husain *et al.*, 2023; Safira *et al.*, 2024; Wardani & Damanhuri, 2024)

Plant cell biology places DNA replication, mitosis, and tissue differentiation as the main foundations for the continuity of organ growth and development. In horticultural plants such as onions, the dynamics of these two processes are crucial to agronomic performance because bulb formation, vegetative vigor, and the expression of superior traits are highly dependent on cell division stability. DNA replication is a critical stage that ensures that each daughter cell receives identical genetic information. However, in the context of genetic engineering, this phase can be modified to produce unusual chromosome structures, namely polyploids. These polyploids then become the starting point for the use of chemical agents such as colchicine in the chromosome engineering process.

Colchicine is a chemical agent that acts specifically on cytoskeletal components, particularly spindle microtubules. It works by binding to tubulin, thereby inhibiting microtubule formation. When the spindle is not formed, chromosomes that have undergone replication in the S phase cannot segregate to opposite cell poles. This condition causes anaphase to stop and cytokinesis to fail, so that the cell retains a double number of chromosomes. The accumulation of cells with double the number of chromosomes forms a polyploid tissue that physiologically shows an increase in nucleus size, cell volume, and stomatal diameter. This effect then contributes to the enlargement of organs such as leaves and tubers, as well as affecting the plant's metabolic response to the environment. This altered physiological environment of the plant then became the basis for comparing the results of the three previous studies.

The differences in the mechanism of action of colchicine, the physiological response of plants, and its implications for genetic engineering based on the three studies reviewed show a uniform mechanistic pattern but with varying phenotypic outputs. The three journals show that colchicine works by inhibiting the formation of spindle microtubules so that replicated chromosomes are unable to segregate normally. This disruption causes an increase in the number of chromosomes (polyploidization), which then manifests in the form of changes in plant phenotype and physiology. Plants that undergo these changes are the subject of further interpretation in the context of onion breeding and genetic engineering.

In journal 1, spindle inhibition by colchicine caused replicated DNA chromosomes to be poorly distributed to daughter cells, resulting in some cells having higher ploidy levels. This condition implies the emergence of morphological diversity, especially variations in leaf color and an increase in the number of tillers at certain

concentrations. However, at doses above 0.4%, the increase in the number of abnormal seedlings shows that the effects of colchicine do not always lead to phenotypic improvement but can be destructive if the concentration is too high. Through these findings, colchicine is positioned as a chemical mutagen that can be used to expand the genetic diversity of the Tajuk onion variety, although its use requires precise dosage regulation to avoid lethality.

Journal 2 shows that chromosome segregation disruption after DNA replication is more effective when colchicine treatment is performed in vitro. In the Sanren variety TSS, colchicine produced pentaploidy at a concentration of 0.75% for 24 hours of treatment. In vitro culture conditions allow colchicine to interact directly with meristem cells so that the polyploidization process is more thorough. The visible phenotypic impact was increased plantlet vigor, particularly root growth and plant height. These findings indicate that in vitro culture is a more effective medium for chromosome engineering to produce new varieties with higher ploidy levels. However, the risk of ploidy instability, such as the emergence of mixoploidy, remains a challenge that requires further cytogenetic verification.

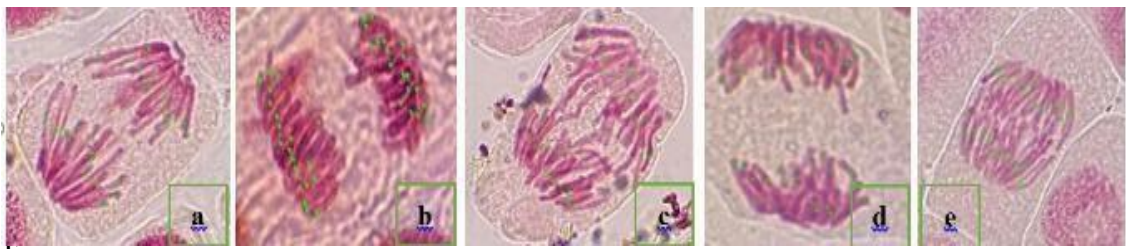


Figure 1. Chromosome image of red onion plants under the following conditions: (a) without colchicine treatment, (b) 1600 ppm colchicine ( ), (c) 3200 ppm, (d) 4800 ppm, and (e) 6400 ppm.

Meanwhile, journal 3 shows that colchicine in ex vitro treatment is also capable of triggering chromosome separation failure after DNA replication, with the formation of triploids at a concentration of 3200 ppm. Changes in stomatal size, number of leaves, and bulb weight at medium doses illustrate that an increase in the number of chromosome copies directly affects cell size and plant metabolic activity. However, doses above 4800 ppm proved to be toxic, as evidenced by reduced growth and higher mortality rates. Thus, the success of polyploidization in the Bima Brebes variety is highly dependent on the balance of colchicine concentration so that the resulting mutations remain stable and do not cause lethal effects. Overall, the three studies show that polyploidization induction through colchicine is an effective conventional genetic

engineering approach to expand genetic diversity and increase the productivity potential of shallots. The main mechanism found in all studies is relatively uniform, namely disruption of post-DNA replication chromosome segregation due to inhibition of microtubule formation. However, plant responses are not homogeneous, as each variety exhibits different levels of physiological tolerance to the cytotoxic stress of colchicine. These differences confirm that the success of polyploidization is determined not only by chemical treatment, but also by the anatomical conditions and physiological status of the tissue at the time of induction.

The variation in response between varieties is closely related to technical factors of treatment, particularly colchicine concentration, duration of exposure, and tissue growth conditions. Excessively high concentrations have been shown to increase the risk of toxicity and inhibit growth, while excessively low concentrations are insufficient to trigger chromosome duplication. The three studies emphasize that the effective range of colchicine is variety-specific. Varieties such as Bima Brebes and TSS Sanren show better consistency in response, while other varieties require dose adjustments to maintain ploidy stability and prevent lethal or mixoploid effects. Thus, protocol optimization needs to be developed gradually based on the physiological characteristics of the variety so that the resulting polyploids are stable and can be maintained in subsequent generations.

These findings have direct implications for the development of shallot varieties. Successfully induced polyploid individuals showed increased cell size, organ enlargement, and indications of strengthened morpho-agronomic characteristics that have the potential to support productivity. The TSS Sanren and Bima Brebes varieties can be considered as the main candidates in the assembly of polyploid varieties because they show a more stable level of induction success. Additionally, standardization of treatment concentration and duration needs to be adjusted according to the physiological sensitivity of the varieties, while the use of tissue culture is recommended to improve consistency of results as it provides a more controlled growth environment and minimizes cell damage due to colchicine toxicity.

## **CONCLUSION**

A literature review shows that polyploidy induction with colchicine is effective in producing superior onion varieties. Colchicine inhibits cell division, resulting in DNA replication without chromosome separation, which produces larger polyploid plants.

Research also confirms that colchicine treatment in in vitro cultures, meristems, and *True Shallot Seeds* (TSS) can increase bulb size, improve morphology, and increase plant vigor. TSS provide additional advantages in the form of longer shelf life, pathogen-free, and more uniform growth. Overall, chromosome manipulation through genetic engineering is a promising method for improving the genetic quality and productivity.

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