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Colchicine-Induced Polyploidy: A Game-Changer for Grasspea Research

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Grasspea (*Lathyrus sativus*) is a resilient legume suited for arid and semi-arid regions, serving as a critical protein source in resource-limited areas. However, its utilization is restricted by the presence of β-ODAP, a neurotoxin linked to lathyrism. Inducing polyploidy through colchicine has emerged as a promising approach to improve grasspea traits. Polyploid grasspea exhibits enhanced genetic variability, higher seed size, improved yield, reduced β-ODAP levels, and better tolerance to abiotic stress. Optimization of colchicine treatments has shown a balance between polyploidy induction efficiency and plant survival. Comparative studies reveal significant agronomic improvements in polyploid plants, including a 44% yield increase and a 55% reduction in toxicity. Despite challenges like sterility and trait stability, polyploid grasspea offers economic and nutritional benefits, addressing food security in marginal regions. Future research aims to enhance trait stability, explore alternative induction methods, and scale field trials to ensure sustainable adoption and impact.

Introduction

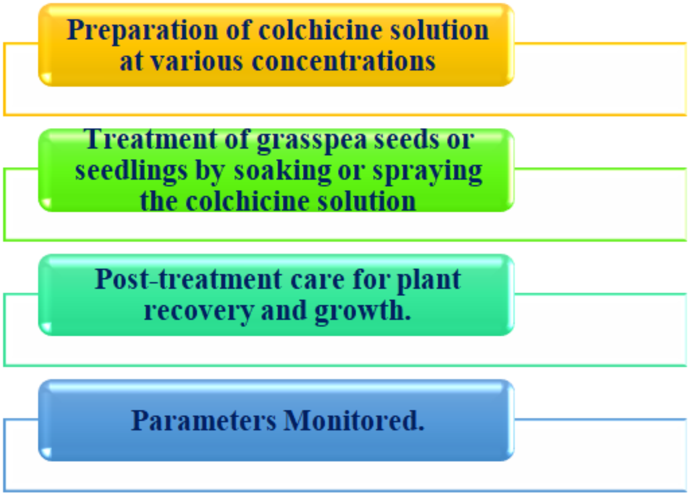
Grasspea (*Lathyrus sativus*) is a robust legume crop known for its adaptability to harsh environments, particularly arid and semi-arid regions (Aloui, 2023). This resilience makes it an essential source of dietary protein, especially in resource-constrained areas where alternative protein-rich foods are scarce. However, the crop's utility is limited by the presence of β-ODAP (β-N-Oxalyl-L-α,β-diaminopropionic acid), a neurotoxin that can lead to lathyrism, a neurological disorder characterized by spastic paralysis in severe cases (Ramya et al., 2022). To address these limitations and enhance the crop's potential, researchers have explored the use of polyploidy, a condition where an organism has multiple sets of chromosomes. Polyploidy, induced through various techniques, offers a significant opportunity for crop improvement. By increasing genetic variability, polyploidy facilitates the development of superior cultivars with desirable traits, including higher yields, larger seeds, and enhanced abiotic stress tolerance (Mo et al., 2020; Nasirvand et al., 2018). Importantly, polyploidy has been shown to reduce β-ODAP levels, thereby mitigating the associated health risks (Mo et al., 2020; Nasirvand et al., 2018). This approach has proven valuable in grasspea breeding programs, paving the way for sustainable cultivation of this critical crop while addressing both food security and nutritional challenges in vulnerable regions.

Colchicine

Colchicine is a chemical compound that disrupts cell division by interfering with the formation of the mitotic spindle, leading to the duplication of chromosome sets (Mo *et al.*, 2020; , Nasirvand *et al.*, 2018). Colchicine is a preferred tool for inducing polyploidy in grasspea research due to its effectiveness and well-understood mechanism of action (Mo *et al.*, 2020; , Nasirvand *et al.*, 2018).

Process of inducing polyploidy

The process of inducing polyploidy in grasspea using colchicine involves the following steps (Mo *et al*., 2020; , Nasirvand *et al*., 2018):



The key parameters monitored in the experiments include (Mo *et al*., 2020; Nasirvand *et al*., 2018):

- Chromosomal analysis to confirm the induction of polyploidy.
- Morphological and physiological changes observed in the treated plants, such as leaf size, stem thickness, and root development.

Optimization of Colchicine Dosage

The efficiency of polyploid induction and plant survival rate are influenced by the concentration of colchicine and the duration of exposure (Mo *et al*., 2020; , Nasirvand *et al*., 2018). Table 1 shows the optimization of colchicine treatments for grasspea, where higher concentrations and longer exposure times resulted in higher polyploidy induction but lower survival rates (Mo *et al*., 2020; Nasirvand *et al*., 2018).

Table 1: Optimization of Colchicine Treatments for Grasspea

Concentration (%)	Exposure Time (hours)	Polyploidy Induction (%)	Survival Rate (%)
0.05	12	50	90
0.1	24	70	80
0.2	48	85	60

Morphological Changes in Polyploid Grasspea

The polyploid grasspea plants exhibited several morphological changes, including increased leaf size, thicker stems, and more robust root systems (Rao & Northup, 2011; Piwowarczyk & Pindel, 2014). Importantly, the polyploid plants also showed a reduction in seed toxicity levels (β-ODAP content) (Ramya *et al*., 2022).

Yield and Agronomic Improvements

The polyploid grasspea plants demonstrated higher seed size and biomass yield compared to their diploid counterparts (Rao & Northup, 2011; Piwowarczyk & Pindel, 2014). They also exhibited better tolerance to abiotic stress conditions, such as drought and heat (Aloui, 2023).

Table 2: Comparative Analysis of Diploid vs. Polyploid Grasspea

Trait	Diploid Grasspea	Polyploid Grasspea	Improvement (%)
Seed Size (g/100)	3.5	5.2	48.6
Biomass Yield (kg/ha)	1800	2600	44.4
β-ODAP Content (%)	0.18	0.08	-55.5

Food Security and Nutritional Value

The development of low-toxin, high-yielding polyploid grasspea cultivars has the potential to address malnutrition and food scarcity in arid and semi-arid regions (Ramya *et al*., 2022). Grasspea is a drought-resistant, high-protein crop that can be cultivated on marginal lands, making it a valuable resource for sustainable food production (Rao & Northup, 2011; , Piwowarczyk & Pindel, 2014).

Breeding Programs and Genetic Diversity

Polyploid grasspea can play a crucial role in hybridization programs to develop superior cultivars with enhanced traits (Rao & Northup, 2011; , Piwowarczyk & Pindel, 2014). The broader genetic base provided by polyploid plants can also help in combating pests and diseases (Rao & Northup, 2011; , Piwowarczyk & Pindel, 2014).

Economic Implications

The production of polyploid grasspea can be cost-effective for smallholder farmers, as it offers higher yields and reduced toxicity levels (Rao & Northup, 2011;Piwowarczyk & Pindel, 2014). Additionally, the reduced incidence of lathyrism-induced healthcare costs can have significant economic benefits for the affected communities (Ramya *et al*., 2022).

Challenges in Colchicine-Induced Polyploidy

While colchicine-induced polyploidy has been successful in grasspea research, there are some challenges to consider, such as the risk of sterility in polyploid plants and the long-term stability of the induced traits across generations (Contreras & Hoskins, 2020).

Future Research Goals

Future research goals in the field of polyploid grasspea include (Wu *et al*., 2022; Mohammadmehdi *et al*., 2021; , Herawati *et al*., 2022; , Tsai *et al*., 2021):

- Enhancing the stability of desired traits through advanced molecular techniques.
- Exploring alternative chemicals or techniques for inducing polyploidy.
- Conducting large-scale field trials to test the performance of polyploid grasspea in different agro-ecological zones.

Table 3: Future Prospects of Polyploid Grasspea Research

Focus Area	Current Status	Future Goals
Trait Stability	Moderate (50% stable traits)	Achieve >90% trait stability
Field Testing	Limited (greenhouse trials)	Large-scale multi-location trials
Farmer Adoption	Low	Promote awareness and subsidies

Key Takeaways

Colchicine-induced polyploidy has transformed grasspea research by enhancing productivity, reducing toxicity, and improving resilience (Mo *et al*., 2020; , Nasirvand *et al*., 2018; , Rao & Northup, 2011; , Piwowarczyk & Pindel, 2014). The adoption of polyploid grasspea can revolutionize legume cultivation in resource-poor regions, contributing to improved food security and sustainable agriculture.

Conclusion

Colchicine-induced polyploidy has revolutionized grasspea research, offering a pathway to enhance its agronomic and nutritional value while reducing β-ODAP-associated risks. The development of polyploid variants with larger seeds, higher yields, and improved stress tolerance addresses the dual challenges of malnutrition and food insecurity in arid and resource-poor regions. Additionally, the broader genetic variability of polyploid grasspea can contribute to breeding programs aimed at combating pests, diseases, and climate challenges. While challenges such as sterility and trait stability persist, ongoing advancements in molecular techniques and optimization strategies hold promise for overcoming these limitations. The economic feasibility and reduced healthcare burden from lathyrism further underscore the crop's transformative potential. By integrating research findings into large-scale cultivation and farmer education programs, polyploid grasspea can play a pivotal role in achieving sustainable agriculture and ensuring food security in vulnerable communities worldwide.

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