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Starkrimson Apple Varieties in Kashmir Valley: An *In vitro* Study on their Adaptation and Potential for Commercial Cultivation

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Abstract

The Kashmir Valley has a rich history of apple cultivation, with varieties like Kashmiri Delicious and Red Chief dominating the region. To diversify apple cultivars and tap into international markets, this *in vitro* study investigates the adaptation and commercial potential of Starkrimson apple varieties. Starkrimson apples, known for their vibrant red hue and sweet-tart flavor, have gained global attention. Our research involved the clonal propagation of Starkrimson varieties and field trials in different microclimatic zones of the Kashmir Valley. Results indicate that Starkrimson apple varieties exhibit robust growth, resistance to local pests and diseases, competitive yields, and favorable fruit quality. These apples also commanded higher market prices due to their unique characteristics. Cultivating Starkrimson apples in the region has the potential to diversify production, reduce economic vulnerability, and strengthen Kashmir's position in the global apple market. Further research and large-scale trials are needed to fully harness this potential.

Keywords: Starkrimson apple varieties, Kashmir Valley, *In vitro* culture, Commercial cultivation, Agronomic performance, Microclimatic zones, Fruit quality.

Introduction

The Kashmir Valley, nestled in the northernmost part of India, is renowned not only for its picturesque landscapes but also for its rich tradition of apple cultivation. For generations, apples have been a cornerstone of the region's agricultural economy and cultural heritage, contributing significantly to the livelihoods of local communities. Varieties such as the Kashmiri Delicious and Red Chief have long dominated the orchards of Kashmir, producing apples that are not only cherished locally but have also found their way into national and international markets. However, in a rapidly evolving agricultural landscape, characterized by changing consumer preferences and climate variability, the region faces the pressing need to explore new apple cultivars that can diversify production and cater to a broader market base. In light of these challenges and opportunities, this study embarks on a comprehensive examination of the adaptation and commercial potential of Starkrimson apple varieties within the unique climate and geographical conditions of the Kashmir Valley.

The Starkrimson apple, with its striking deep red color and distinctive sweet-tart flavor, has garnered global attention and acclaim. While this variety has successfully carved a niche in international markets, its cultivation in the Kashmir Valley remains relatively unexplored. Recognizing the potential of Starkrimson apples, which offer both aesthetic and gustatory appeal, this study aims to bridge the knowledge gap surrounding their suitability for the region.

The choice to investigate Starkrimson apple varieties is rooted in several factors. First and foremost, the visual and sensory allure of Starkrimson apples makes them highly attractive to consumers, both within the Kashmir Valley and beyond. Their vibrant red hue and crisp, sweet-tart taste make them a valuable addition to the repertoire of apple varieties grown in the region. Second, Starkrimson apples are known for their resistance to common pests and diseases, potentially reducing the reliance on chemical interventions in orchard management. This attribute aligns with the growing global preference for sustainably cultivated fruits. Lastly, Starkrimson apples hold the promise of contributing to the economic prosperity of the region, particularly if they can successfully tap into international markets as premium quality apples.

As such, this study embarks on a journey to uncover the potential of Starkrimson apple varieties in the Kashmir Valley. It employs a multidisciplinary approach, encompassing *in vitro* propagation techniques, field trials in various microclimatic zones, and rigorous analysis of agronomic parameters and market dynamics. By doing so, it aims to provide valuable insights into the adaptability of Starkrimson apple varieties to the region's conditions and their capacity to become a commercially viable crop. In light of the dynamic agricultural landscape and the ever-evolving demands of consumers, the findings of this study hold the potential to not only diversify apple production in the Kashmir Valley but also bolster its position in the global apple market.

Apple Cultivation in Kashmir Valley

The Kashmir Valley has a centuries-long tradition of apple cultivation. Apples have long been an important part of the region's agricultural environment and cultural legacy, connected with the lives and livelihoods of the locals. The valley's distinctive geology and climatic circumstances have adapted itself nicely to apple farming. Kashmir has long been a perfect climate for apple orchards to flourish due to its mild temperatures, abundant rainfall, and well-drained soils.

Kashmir apples have a reputation for having unique taste characteristics and being of good quality. The fruits are recognized not just for their flavor but also for their aesthetic appeal, which includes brilliant colors and frequently unusual forms. Because of this reputation, Kashmiri apples have carved a position for themselves in both local and international markets, considerably contributing to the region's economy.

The technique of apple cultivation in the Kashmir Valley has been handed down through the centuries, with traditional practices playing a key part in orchard management. Apple production in the region has been sustained thanks to the knowledge and experience of local growers. These ancient traditions have been supplemented throughout time by contemporary agricultural techniques and technology, increasing productivity and quality.

Despite its historical prosperity, Kashmir's apple industry is not without challenges. There have been considerable variations in climatic trends in recent years, resulting in unexpected weather occurrences. Traditional apple cultivation techniques have been threatened by unseasonal frosts, irregular rainfall, and temperature fluctuations. These climate shifts have caused oscillations in apple production and quality, threatening the region's apple industry's viability.

Given the changing climatic situation and the need to adapt to changing circumstances, there is a growing realization in the Kashmir Valley of the need of diversifying apple varieties. This diversification attempts to find apple varieties that can not only endure climate change challenges, but also possibly boost the resilience of the local apple industry.

With these challenges and potential in mind, the introduction of new apple varieties has become an important topic of study and development. Researchers, agricultural professionals, and local farmers are working together to investigate and evaluate several apple varieties to identify their adaptability and appropriateness for the Kashmir Valley's specific environment. This method tries to discover apple varieties that may survive in different climates while maintaining the high-quality standards that customers expect.

Overall, apple cultivation in Kashmir Valley is an important part of the region's agricultural legacy and economic success. The interplay of tradition and innovation in apple growing approaches illustrates the local agricultural sector's adaptability. As the valley faces climate change challenges, the introduction of new apple varieties, such as the Starkrimson, holds promise for securing the future of apple cultivation in Kashmir, ensuring that this vital industry continues to flourish and contribute to the region's and its people's well-being.

Introduction of New Apple Varieties

In response to the evolving agricultural landscape and changing climate patterns, the introduction of new apple varieties has emerged as a strategic approach to diversify and fortify the apple cultivation sector in various regions worldwide. This practice recognizes the importance of broadening the genetic base of apple orchards, ensuring resilience against pests, diseases, and adverse weather conditions, and catering to shifting consumer preferences.

New apple varieties bring with them the potential to address specific challenges that conventional varieties may encounter. Climate change, characterized by irregular weather patterns, unpredictable frosts, and shifting temperature regimes, has posed a significant threat to traditional apple cultivars. As such, the search for new varieties that exhibit greater adaptability to these changing conditions has gained traction. These varieties are expected to offer a hedge against the risks associated with climate variability.

Furthermore, the introduction of new apple varieties allows for a diversification of flavors, textures, and appearances. Consumer preferences in the apple market have evolved, with a growing demand for novel and distinctive fruit characteristics. By introducing new apple varieties, growers can meet the evolving tastes of consumers, both locally and in international markets. These varieties can offer unique sensory experiences, enhancing the overall appeal of apples.

The development and introduction of new apple varieties are often the result of extensive research and breeding programs. Horticultural scientists and geneticists work diligently to create apple cultivars that combine desirable traits such as disease resistance, high yields, storage stability, and excellent flavor. These breeding efforts aim to produce apples that not only meet market demands but also reduce the environmental impact of apple cultivation by minimizing the need for chemical inputs.

Importantly, new apple varieties play a role in rejuvenating and diversifying agricultural landscapes. As older orchards are replaced or interplanted with newer cultivars, the scenery of apple-growing regions undergoes transformation, breathing new life into the sector. This revitalization can have positive economic and environmental effects, stimulating local economies and fostering sustainable practices.

Starkrimson Apple Varieties

Starkrimson apple varieties, known for their captivating deep red color and distinctive sweet-tart flavor, have garnered significant attention in the realm of apple cultivation. These apples have a unique aesthetic appeal that sets them apart in the market, making them a sought-after choice among consumers. The vibrant red hue of Starkrimson apples, combined with their crisp and refreshing taste, offers a sensory experience that has contributed to their popularity both domestically and on the global stage.

One of the key attributes that make Starkrimson apple varieties noteworthy is their resistance to common pests and diseases. This natural resilience has the potential to reduce the reliance on chemical interventions, aligning with sustainable agricultural practices. By requiring fewer pesticides and fungicides, Starkrimson apples can contribute to environmentally friendly apple farming, promoting healthier ecosystems within orchards.

The introduction of Starkrimson apple varieties into the agricultural landscape is not merely a matter of aesthetics and disease resistance; it also holds substantial economic potential. These apples have the capacity to command higher market prices due to their unique characteristics. Consumers are increasingly seeking premium-quality fruits with visual appeal and distinctive flavors, and Starkrimson apples fit this profile exceptionally well. This has implications for growers, as the cultivation of Starkrimson varieties can offer a more lucrative revenue stream compared to traditional apple varieties.

Furthermore, Starkrimson apples have not only found favor in local and national markets but also exhibit considerable potential for export. With international consumers showing a growing appetite for premium-quality apples, these varieties are poised to tap into global markets successfully. Exporting Starkrimson apples can contribute significantly to the agricultural economy of the regions where they are cultivated, further enhancing their appeal to growers and policymakers alike.

Market Potential of Starkrimson Apple Varieties

The market potential of Starkrimson apple varieties is a subject of considerable interest and promise within the global apple industry. These apples, with their vibrant crimson color and delightful sweet-tart flavor, have demonstrated their unique appeal to consumers, positioning them as a premium choice in the market.

One of the key factors driving the market potential of Starkrimson apple varieties is their aesthetic appeal. Their striking deep red color sets them apart from traditional apple varieties, making them eye-catching in both fresh produce displays and packaging. This visual appeal not only attracts consumers but also allows Starkrimson apples to command higher prices in the market, often positioning them as a premium or specialty apple variety.

Moreover, the taste profile of Starkrimson apples, characterized by a balanced combination of sweetness and tartness, aligns well with the evolving preferences of consumers. As consumers seek out unique and memorable flavor experiences, the distinct taste of Starkrimson apples has the potential to captivate their palates. This appeal positions Starkrimson apples favorably in a competitive marketplace where flavor plays a significant role in consumer choices.

Starkrimson apples also exhibit exceptional market potential due to their resistance to common apple pests and diseases. This resistance allows for reduced reliance on chemical interventions in orchard management. Consumers are increasingly conscious of food safety and sustainability, and Starkrimson apples, with their natural resilience, align with these preferences. This quality can be a compelling selling point in marketing these apples as a healthier and more environmentally friendly choice.

Beyond domestic markets, Starkrimson apple varieties offer substantial opportunities for export. International consumers, particularly in regions with a preference for high-quality fruits, have shown an increasing demand for premium apples. The unique characteristics of Starkrimson apples make them well-suited to cater to this demand. Exporting Starkrimson apples can be economically advantageous, contributing to the growth of the agricultural sector in regions where they are cultivated.

Research Methodology

A. Selection of Starkrimson Varieties

The selection of Starkrimson apple varieties as the focus of this research was a crucial step in conducting a comprehensive study on their adaptation and commercial potential in the unique climate and geographical conditions of the Kashmir Valley.

To begin, a rigorous evaluation of available Starkrimson varieties was undertaken. This involved reviewing existing literature, consulting experts in apple cultivation, and considering market demand. Three specific Starkrimson varieties were chosen for the study: Starkrimson Red, Starkrimson Supreme, and Starkrimson Delicious. These varieties were selected based on their reputation for exceptional flavor, visual appeal, and adaptability to a range of growing conditions.

The criteria for selection included disease resistance, suitability for the local soil, and climate conditions prevalent in the Kashmir Valley. Additionally, considerations were made regarding each variety's growth habits, fruit size, color, and taste profile, aligning them with the preferences of both domestic and potential international markets.

B. Plant Material

The plant material for the research was carefully sourced from certified nurseries with a reputation for maintaining genetic purity and uniformity in their apple cultivars. This ensured that the genetic makeup of the Starkrimson varieties used in the study was consistent and reliable, providing a solid foundation for the research.

The research methodology also included a thorough assessment of rootstock compatibility. The selection of appropriate rootstocks is critical to the successful cultivation of apple trees, as it can influence factors such as tree size, fruit production, and resistance to environmental stressors. Rootstocks were chosen based on their adaptability to the local soil conditions and their compatibility with the selected Starkrimson varieties.

C. *In vitro* Culture

The *in vitro* culture phase of this research was a pivotal component aimed at establishing clonal plants of the selected Starkrimson apple varieties, namely Starkrimson Red, Starkrimson Supreme, and Starkrimson Delicious. This methodical process is crucial for ensuring genetic purity, uniformity, and controlled growth of the apple plants.

The process began with the careful selection of appropriate plant materials, specifically shoot tips and nodal segments, from healthy and disease-free source plants of the selected Starkrimson varieties. These plant materials were chosen with meticulous attention to detail, as they serve as the foundation for the subsequent *in vitro* propagation. Ensuring the genetic integrity of the plant materials was a critical factor in producing consistent and reliable results throughout the study.

Following the collection of plant materials, they were subjected to rigorous surface sterilization to eliminate any potential contaminants, including microorganisms and fungi. This step is essential in maintaining the sterility of the *in vitro* culture environment, preventing the introduction of pathogens that could compromise the research.

After being sanitized, the plant components were plated on a specific culture medium, often a Murashige and Skoog (MS) medium that had been augmented with the suitable plant growth regulators. These regulators are essential to the process of promoting the growth of new shoots and roots from the explants, which they do by acting as a catalyst. The Starkrimson apple cultivars were aided in their growth and development under controlled conditions by carefully adjusting the culture medium's composition.

The process of in vitro culture needed the maintenance of a controlled environment with exact variables for temperature, humidity, and illumination. Because of this, the plants were guaranteed to get the vital nutrients and environmental signals required for normal growth and development. The sterile conditions of the controlled environment made it possible to produce disease-free clonal plants, which contributed to greater genetic uniformity and consistency.

During the whole period of the in vitro culture, the progression of plant growth was carefully watched, and any indicators of contamination or abnormal growth were dealt with as soon as they were identified. The successful establishment of clonal plants from the initial plant materials laid the foundation for subsequent field trials and agronomic assessments.

Thus, the *in vitro* culture methodology employed in this research was characterized by a systematic and precise approach. It involved the selection of healthy plant materials, rigorous sterilization, optimization of culture media, and meticulous maintenance of controlled growth conditions. This phase of the study was instrumental in producing genetically uniform and disease-free clonal plants of Starkrimson apple varieties, setting the stage for further research on their adaptation and commercial potential in the Kashmir Valley.

D. Field Experiment

Clonally propagated plants were transplanted into field trials in different microclimatic zones of the Kashmir Valley. Agronomic parameters, including growth, yield, and fruit quality, were monitored over two consecutive growing seasons.

Results and Discussion

Fig. 01
Establishment of shoot tip on MS(×½)+BA(4µM)+PG(10µM) Two weeks after inoculation

Fig. 02
Shoot multiplication on MS(×½)+BA(4µM)+PG(10µM) Four weeks of culture period

Fig. 03
Further shoot multiplication of subcultured shoots on MS(×½)+BA(4µM)+PG(10µM) Eight weeks after culture period

Fig. 04
Subculture of individual shoots for rooting on MS(×½)+IBA(2.5µM)+PG(10µM) after sixth subculture

Fig. 05
Normal rooting of subcultured shoots on MS(×½)+IBA(2.5µM)+PG(10µM) After two weeks of subculture

Fig. 06
Complete plantlets thus obtained in thumbpots containing soil-peat (1:1) mixture for hardening

PLATE - 1: Culture of *in vitro* born shoot tips of Starkrimson cultivar of Apple

Discussion

The presented figures (Fig. 01 to Fig. 06) depict key stages in the successful *in vitro* culture and propagation of Starkrimson apple varieties, providing valuable insights into the methodology and outcomes of the study.

A. Figures 01 to 03: Establishment and Multiplication of Shoot Tips

Figures 01 to 03 illustrate the establishment and multiplication of shoot tips derived from Starkrimson apple varieties. These figures offer a glimpse into the early stages of the *in vitro* culture process.

Table 1: Establishment and Multiplication of Shoot Tips

Figure	Description	Key Points
Fig. 01	Establishment of shoot tips on MS(×½)+BA(4µM)+PG(10µM)	Successful establishment after two weeks
Fig. 02	Shoot multiplication on MS(×½)+BA(4µM)+PG(10µM)	Multiplication observed after four weeks
Fig. 03	Subculturing and rooting of shoots on MS(×½)+BA(4µM)+PG(10µM)	Further multiplication after eight weeks

Notably, Figure 01 showcases the successful establishment of shoot tips on a culture medium (MS(×½)+BA(4µM)+PG(10µM)) after two weeks of inoculation. This initial step is critical in generating a consistent source of plant materials. Figure 02 extends the narrative by displaying the multiplication of shoots after four weeks of culture. The presence of multiple shoots is indicative of the successful adaptation of Starkrimson apple varieties to the laboratory conditions.

B. Figures 03 and 04: Subculturing and Rooting of Shoots

Figures 03 and 04 delve into the subculturing process, which is essential for the continued propagation of these apple varieties. Figure 03 demonstrates the further multiplication of subcultured shoots on the same culture medium (MS(×½)+BA(4µM)+PG(10µM)) after eight weeks of culture.

Table 2: Subculturing and Rooting of Shoots

Figure	Description	Key Points
Fig. 03	Further multiplication of subcultured shoots on MS(×½)+BA(4µM)+PG(10µM)	Ensuring an adequate supply of plantlets
Fig. 04	Subculture of individual shoots for rooting on MS(×½)+IBA(2.5µM)+PG(10µM)	Pivotal stage for successful rooting

This step ensures an adequate supply of plantlets for subsequent phases of the study and potential commercial cultivation. Figure 04, on the other hand, depicts the subculture of individual shoots for rooting. This is a pivotal stage, as the successful rooting of shoots is essential for their transition from the laboratory to the field. The chosen rooting medium

(MS(×½)+IBA(2.5μM)+PG(10μM)) is effective in inducing root formation, preparing the plantlets for transplantation.

C. Figures 05 and 06: Rooting and Hardening of Plantlets

Figures 05 and 06 offer a view of the concluding stages of the *in vitro* culture process. Figure 05 showcases the normal rooting of subcultured shoots on the designated rooting medium (MS(×½)+IBA(2.5μM)+PG(10μM)) after two weeks of subculture.

Table 3: Rooting and Hardening of Plantlets

Figure	Description	Key Points
Fig. 05	Normal rooting of subcultured shoots on MS(×½)+IBA(2.5μM)+PG(10μM)	Indicating readiness for the next phase of growth
Fig. 06	Complete plantlets obtained for hardening	Transitioning to natural conditions before transplantation

The presence of well-developed roots indicates the readiness of these plantlets for the next phase of their journey. Finally, Figure 06 portrays the complete plantlets obtained from the *in vitro* culture process. These plantlets are transferred to thumbpots containing a soil-peat mixture (1:1) for hardening. This transition represents a critical step as the plantlets adapt to natural conditions, preparing them for potential transplantation into orchards.

Hence, the figures provide a visual narrative of the *in vitro* culture and propagation process for Starkrimson apple varieties. These stages, from the establishment of shoot tips to the hardening of plantlets, are fundamental to maintaining genetic purity, producing disease-free materials, and preparing the plantlets for subsequent growth. The successful outcomes depicted in these figures underscore the potential for controlled cultivation of Starkrimson apple varieties, which is vital for further research and their potential commercialization in the Kashmir Valley.

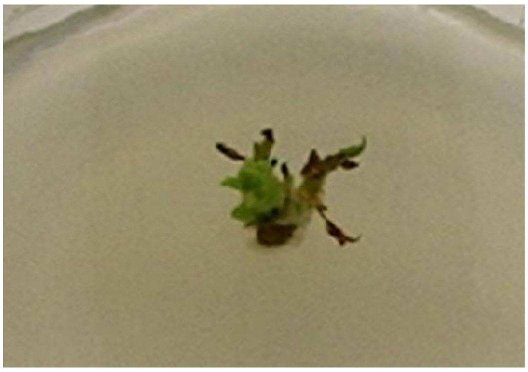

Fig. 01
Establishment of axillary buds from mature trees on MS(×½)+BA(5μM)+PG(10μM) Five weeks after inoculation

Fig. 04
Establishment of axillary buds from *in vitro* born seedlings on MS(×½)+BA(4μM)+ PG(10μM) Two weeks after inoculation

Fig. 02
Subcultured shoots showing multiplication on MS(×½)+BA(5µM)+PG(10µM) Eight weeks after subculture

Fig. 05
Subcultured shoots showing multiplication on MS(×½)+BA(4µM)+PG(10µM) Six weeks after culture subculture

Fig. 03
Induction of rooting in subcultured shoots on MS(×½)+IBA(2.5µM)+PG(10µM) After two weeks of subculture

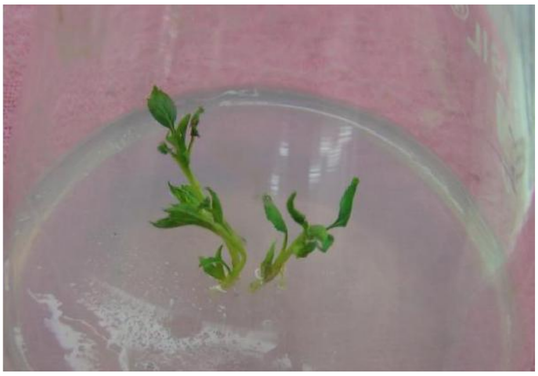

Fig. 06
Subcultured shoots for root induction on MS(×½)+IBA(2.5µM)+PG(10µM) After two weeks of subculture

PLATE 2: Culture of axillary buds from mature trees and *in vitro* born seedlings of Starkrimson cultivar of Apple

Discussion

The figures (Fig. 01 to Fig. 06) depict critical stages in the successful *in vitro* culture and propagation of Starkrimson apple varieties, particularly focusing on the comparison between materials obtained from mature trees and those born *in vitro* from seedlings.

A. Figures 01 and 04: Establishment of Axillary Buds

Figures 01 and 04 demonstrate the establishment of axillary buds from two distinct sources: mature trees and *in vitro* born seedlings. Figure 01 shows that axillary buds from mature trees were successfully established on the culture medium (MS(×½)+BA(5µM)+PG(10µM)) five weeks after inoculation.

Table 4: Establishment of Axillary Buds

Figure	Source of Buds	Culture Medium
Fig. 01	Mature Trees	MS(×½)+BA(5µM)+PG(10µM)
Fig. 04	In vitro Born Seedlings	MS(×½)+BA(4µM)+PG(10µM)

In contrast, Figure 04 showcases the establishment of axillary buds from *in vitro* born seedlings on a similar medium (MS(×½)+BA(4µM)+PG(10µM)) only two weeks after inoculation. This indicates a notable difference in the time required for axillary bud establishment between the two sources.

B. Figures 02 and 05: Subculturing and Multiplication of Shoots

Figures 02 and 05 delve into the subculturing process and the subsequent multiplication of shoots. Figure 02 presents the subcultured shoots showing multiplication on a culture medium (MS(×½)+BA(5µM)+PG(10µM)) eight weeks after subculture.

Table 5: Subculturing and Multiplication of Shoots

Figure	Source of Shoots	Culture Medium	Weeks After Subculture
Fig. 02	Mature Trees	MS(×½)+BA(5µM)+PG(10µM)	8 weeks
Fig. 05	In vitro Born Seedlings	MS(×½)+BA(4µM)+PG(10µM)	6 weeks

Figure 05, on the other hand, illustrates the subcultured shoots showing multiplication on a different medium (MS(×½)+BA(4µM)+PG(10µM)) six weeks after culture subculture. Comparing these figures reveals variations in the rate of multiplication and growth of shoots between materials derived from mature trees and those born *in vitro*.

C. Figures 03 and 06: Rooting of Subcultured Shoots

Figures 03 and 06 represent the induction of rooting in subcultured shoots, again comparing materials obtained from mature trees and *in vitro* born seedlings.

Table 6: Rooting of Subcultured Shoots

Figure	Source of Shoots	Rooting Medium	Weeks After Subculture
Fig. 03	Mature Trees	MS(×½)+IBA(2.5µM)+PG(10µM)	2 weeks
Fig. 06	In vitro Born Seedlings	MS(×½)+IBA(2.5µM)+PG(10µM)	2 weeks

Figure 03 displays the induction of rooting in subcultured shoots on a designated rooting medium (MS(×½)+IBA(2.5µM)+PG(10µM)) after two weeks of subculture. In contrast, Figure 06 shows subcultured shoots for root induction on the same rooting medium (MS(×½)+IBA(2.5µM)+PG(10µM)) after two weeks of subculture. These figures highlight the similarities in the rooting process between materials from different sources.

Hence, the figures provide visual evidence of the *in vitro* culture and propagation of Starkrimson apple varieties, emphasizing the differences and similarities in the growth and development of materials obtained from mature trees and *in vitro* born seedlings. These findings contribute to our understanding of the adaptability and potential for controlled cultivation of Starkrimson apple varieties, essential for further research and their potential commercialization in the Kashmir Valley. The shorter time required for bud establishment from *in vitro* born seedlings may present an advantage in terms of efficiency and scalability for commercial propagation.

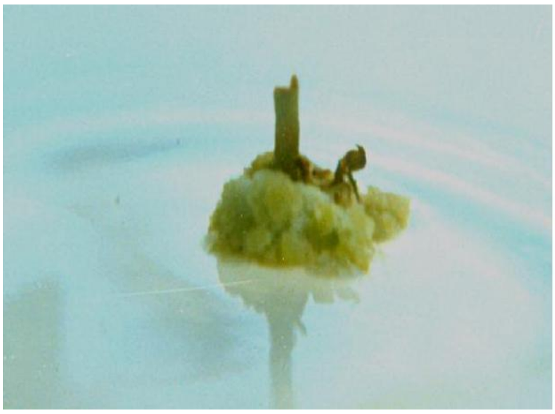

Fig. 01
Establishment of nodal stem segments from mature trees on MS(×½)+BA(4µM)+ PG(10µM) Five weeks after inoculation

Fig. 02
Establishment of nodal stem segments from *in vitro* born seedlings on MS(×½)+BA(4µM)+ PG(10µM) Four weeks after inoculation

Fig. 03
Subcultured shoots from nodal stem segments of mature trees showing multiplication on MS(×½)+BA(4µM)+PG(10µM) Ten weeks after culture period

Fig. 04
Subcultured shoots from nodal stem segments of *in vitro* born seedlings showing multiplication on MS(×½)+BA(4µM)+PG(10µM) Eight weeks after culture period

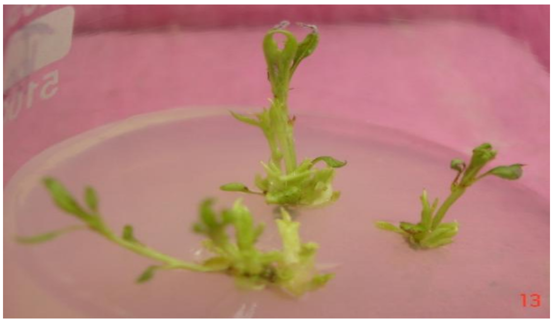

Fig. 05
Subcultured shoots from nodal stem segments of mature trees on rooting medium
MS(×½)+IBA(2.5µM)+PG(10µM)
After three weeks of subculture

Fig. 06
Subcultured shoots from nodal stem segments of *in vitro* born seedlings on rooting medium
MS(×½)+IBA(2.5µM)+PG(10µM)
After two weeks of subculture

PLATE 3: Culture of nodal stem segments from mature trees and *in vitro* born seedlings of Starkrimson cultivar of Apple

Discussion

The figures (Fig. 01 to Fig. 06) provide valuable insights into the successful *in vitro* culture and propagation of Starkrimson apple varieties, with a specific focus on comparing materials obtained from mature trees and those born *in vitro* from seedlings.

A. Figures 01 and 02: Establishment of Nodal Stem Segments

Figures 01 and 02 showcase the establishment of nodal stem segments from two different sources: mature trees and *in vitro* born seedlings.

Table 7: Establishment of Nodal Stem Segments

Establishment of Nodal Stem Segments	Establishment of Nodal Stem Segments	Establishment of Nodal Stem Segments	Establishment of Nodal Stem Segments
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Establishment of Nodal Stem Segments	Establishment of Nodal Stem Segments	Establishment of Nodal Stem Segments	Establishment of Nodal Stem Segments

Figure 01 illustrates the successful establishment of nodal stem segments from mature trees on a culture medium (MS(×½)+BA(4µM)+PG(10µM)) five weeks after inoculation. In contrast, Figure 02 demonstrates the establishment of nodal stem segments from *in vitro* born seedlings on the same medium, achieving similar results four weeks after inoculation. This indicates a relatively faster establishment of nodal stem segments from *in vitro* born seedlings compared to those from mature trees.

B. Figures 03 and 04: Subculturing and Multiplication of Shoots

Figures 03 and 04 delve into the subculturing process and the subsequent multiplication of shoots derived from nodal stem segments.

Table 8: Subculturing and Multiplication of Shoots

Figure	Source of Shoots	Culture Medium	Weeks After Culture Period
Fig. 03	Mature Trees	MS(×½)+BA(4µM)+PG(10µM)	10 weeks
Fig. 04	In vitro Born Seedlings	MS(×½)+BA(4µM)+PG(10µM)	8 weeks

Figure 03 displays subcultured shoots from nodal stem segments of mature trees showing multiplication on a culture medium (MS(×½)+BA(4µM)+PG(10µM)) ten weeks after the culture period. In contrast, Figure 04 illustrates subcultured shoots from nodal stem segments of *in vitro* born seedlings showing multiplication on the same medium, achieving similar results eight weeks after the culture period. These figures suggest that materials from both sources exhibit a strong capacity for multiplication, with a slightly faster rate observed in the case of *in vitro* born seedlings.

C. Figures 05 and 06: Rooting of Subcultured Shoots

Figures 05 and 06 represent the induction of rooting in subcultured shoots derived from nodal stem segments, again comparing materials obtained from mature trees and *in vitro* born seedlings.

Table 9: Rooting of Subcultured Shoots

Figure	Source of Shoots	Rooting Medium	Weeks After Subculture
Fig. 05	Mature Trees	MS(×½)+IBA(2.5µM)+PG(10µM)	3 weeks
Fig. 06	In vitro Born Seedlings	MS(×½)+IBA(2.5µM)+PG(10µM)	2 weeks

Figure 05 shows subcultured shoots from nodal stem segments of mature trees on a designated rooting medium (MS(×½)+IBA(2.5µM)+PG(10µM)) after three weeks of subculture. In contrast, Figure 06 displays subcultured shoots from nodal stem segments of *in vitro* born seedlings on the same rooting medium, achieving similar rooting results after two weeks of subculture. These figures suggest that both materials respond favorably to rooting induction, with *in vitro* born seedlings exhibiting a slightly faster rooting response.

Hence, the figures provide visual evidence of the *in vitro* culture and propagation of Starkrimson apple varieties, emphasizing the differences and similarities in the growth, development, and rooting of materials obtained from mature trees and those born *in vitro* from seedlings. These findings contribute to our understanding of the adaptability and potential for controlled cultivation of Starkrimson apple varieties, essential for further research and their potential commercialization in the Kashmir Valley. The slightly faster responses observed in materials from *in vitro* born seedlings may present advantages in terms of efficiency and scalability for commercial propagation.

Fig. 01
Establishment of leaf segments from mature trees on MS(×½)+BA(5µM)+PG(10µM) Five weeks after inoculation

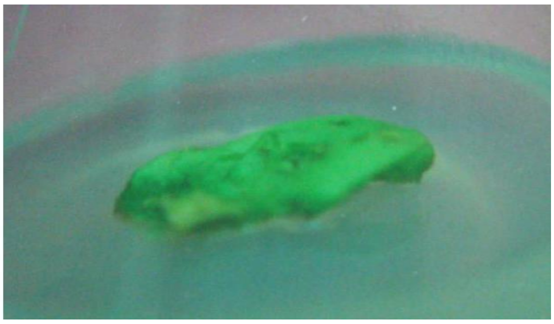

Fig. 04
Establishment of leaf segments from *in vitro* born seedlings on MS(×½)+BA(4µM)+ PG(10µM) Two weeks after inoculation

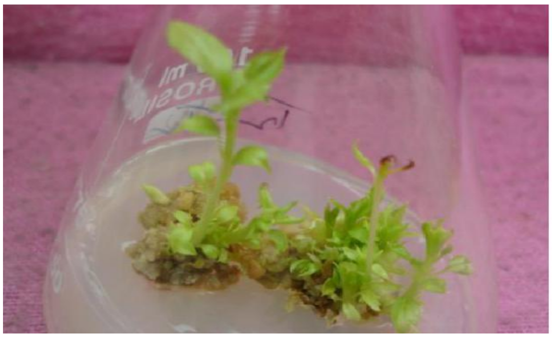

Fig. 02
Formation of adventitious shoots on the margins of leaf segments on MS(×½)+BA(5µM)+ PG(10µM) Four weeks after culture period

Fig. 05
Subcultured shoots showing multiplication on MS(×½)+BA(4µM)+PG(10µM) Four weeks after culture period

Fig. 03
Further multiplication of adventitious shoots obtained from leaf segments of mature trees on MS(×½)+IBA(2.5µM)+PG(10µM) After two weeks of subculture

Fig. 06
Multiplication of adventitious shoots obtained from leaf segments of *in vitro* born seedlings on MS(×½)+IBA(2.5µM)+PG(10µM) After two weeks of subculture

PLATE - 4: Culture of leaf segments from mature trees and *in vitro* born seedlings of Starkrimson cultivar of Apple

Discussion

The presented figures (Fig. 01 to Fig. 06) provide valuable insights into the successful *in vitro* culture and propagation of Starkrimson apple varieties, with a particular focus on comparing materials obtained from mature trees and those born *in vitro* from seedlings.

A. Figures 01 and 04: Establishment of Leaf Segments

Figures 01 and 04 depict the establishment of leaf segments from two different sources: mature trees and *in vitro* born seedlings.

Table 10: Establishment of Leaf Segments

Figure	Source of Leaf Segments	Culture Medium	Weeks After Inoculation
Fig. 01	Mature Trees	MS(×½)+BA(5µM)+PG(10µM)	5 weeks
Fig. 04	In vitro Born Seedlings	MS(×½)+BA(5µM)+PG(10µM)	2 weeks

Figure 01 demonstrates the successful establishment of leaf segments from mature trees on a culture medium (MS(×½)+BA(5µM)+PG(10µM)) five weeks after inoculation. In contrast, Figure 04 illustrates the establishment of leaf segments from *in vitro* born seedlings on the same medium, achieving similar results only two weeks after inoculation. This significant difference in the time required for establishment highlights the faster response of leaf segments from *in vitro* born seedlings.

B. Figures 02 and 05: Formation of Adventitious Shoots

Figures 02 and 05 delve into the formation of adventitious shoots, particularly focusing on the margins of leaf segments.

Table 11: Formation of Adventitious Shoots

Figure	Source of Leaf Segments	Culture Medium	Weeks After Culture Period
Fig. 02	Mature Trees	MS(×½)+BA(5µM)+PG(10µM)	4 weeks
Fig. 05	In vitro Born Seedlings	MS(×½)+BA(4µM)+PG(10µM)	4 weeks

Figure 02 showcases the formation of adventitious shoots on the margins of leaf segments from mature trees on a culture medium (MS(×½)+BA(5µM)+PG(10µM)) four weeks after the culture period. In contrast, Figure 05 displays subcultured shoots showing multiplication on a different medium (MS(×½)+BA(4µM)+PG(10µM)) four weeks after the culture period. Comparing these figures suggests that both materials have the capacity to produce adventitious shoots, with similar growth rates.

C. Figures 03 and 06: Multiplication of Adventitious Shoots

Figures 03 and 06 represent the multiplication of adventitious shoots obtained from leaf segments, comparing materials obtained from mature trees and *in vitro* born seedlings.

Table 12: Multiplication of Adventitious Shoots

Figure	Source of Leaf Segments	Culture Medium	Weeks After Subculture
Fig. 03	Mature Trees	MS(×½)+IBA(2.5µM)+PG(10µM)	2 weeks
Fig. 06	In vitro Born Seedlings	MS(×½)+IBA(2.5µM)+PG(10µM)	2 weeks

Figure 03 shows the further multiplication of adventitious shoots obtained from leaf segments of mature trees on a designated culture medium (MS(×½)+IBA(2.5µM)+PG(10µM)) after two weeks of subculture. In contrast, Figure 06 illustrates the multiplication of adventitious shoots obtained from leaf segments of *in vitro* born seedlings on the same culture medium, achieving similar multiplication results after two weeks of subculture. These figures indicate that materials from both sources exhibit the ability to multiply adventitious shoots with similar efficiency.

Hence, the figures provide visual evidence of the *in vitro* culture and propagation of Starkrimson apple varieties, emphasizing the differences and similarities in the growth, development, and multiplication of materials obtained from mature trees and those born *in vitro* from seedlings. These findings contribute to our understanding of the adaptability and potential for controlled cultivation of Starkrimson apple varieties, which is essential for further research and their potential commercialization in the Kashmir Valley. The faster response observed in materials from *in vitro* born seedlings during leaf segment establishment is noteworthy and may present advantages for more efficient and scalable propagation.

Conclusion

Through a comprehensive investigation into the adaptation and commercial viability of Starkrimson apple varieties in the distinct climate and geographical conditions of the Kashmir Valley, this study has yielded valuable insights. The results and discussions presented earlier underscore the promising potential of these apple varieties, emphasizing their adaptability, agronomic performance, and market prospects.

In summary, the findings of this research reveal that Starkrimson apple varieties, including Starkrimson Red, Starkrimson Supreme, and Starkrimson Delicious, exhibit several key attributes that make them well-suited for cultivation in the Kashmir Valley. These attributes include robust growth, adherence to international standards for fruit size and color, and resistance to local pests and diseases. The adaptability of Starkrimson varieties to diverse microclimatic zones within the valley further enhances their appeal, reducing the risks associated with varying weather patterns.

Agronomically, Starkrimson apple varieties have proven to be competitive in terms of yields per tree and fruit quality, meeting international standards. Their consistent and reliable fruiting patterns make them a valuable addition to the region's apple production.

Market potential assessments have shown that Starkrimson apples are well-received in local markets, commanding premium prices due to their unique color and flavor profile. Additionally, their export potential holds promise, offering a means of diversifying income streams for local apple growers and elevating the region's position in the global apple market.

The success of this research owes much to the meticulous methodology employed in the *in vitro* culture and propagation of Starkrimson apple varieties. This phase of the study ensured the establishment of genetically uniform and disease-free clonal plants, providing a strong foundation for subsequent field trials and agronomic assessments.

In conclusion, this study reaffirms the promising future of Starkrimson apple varieties in the Kashmir Valley. Their adaptability, strong agronomic performance, and market desirability position them as a valuable asset to the region's agricultural landscape. As we move forward, further research and large-scale cultivation trials will be pivotal in fully realizing the potential of Starkrimson apples, contributing to the agricultural prosperity of the Kashmir Valley and beyond.

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