**Performance evaluation of dwarfing rootstock under open field and protected structure in cold arid region of Ladakh**

**ABSTRACT**

The basics of a productive and healthy orchard are the rootstocks that provide anchorage, water and nutrients essential to the above-ground portions of the trees. Thus, rootstock play crucial role in determining productive and healthy orchard efficiency in fruit crops by directly influence on the production of flower and fruits setting. The present study explores the performance evaluation of dwarfing rootstock under open field and protected structure in cold arid region of Ladakh. A two factorial Randomized Block Design with four replications was carried out at Krishi Vigyan Kendra Kargil-, SKUAST-K Kargil Ladakh. The saplings were dugout in the month of March when the temperature is favorable, planted both in open field as well as under hi-tech polyhouse. Individual data at each treatment, representing a combination of rootstock and environmental condition, was replicated four times to ensure reliability and accuracy of the results. Data from the observation were also subjected to analysis of variance (ANOVA) to compare the means of the different rootstock and different environmnet condition for each parameter. Statistical significance was determined at a 5% level (p ≤ 0.05). Among all the dwarfing rootstock M111 recorded maximum plant height, number of shoots, and stock girth followed by M106 under both open filed and hi-tech poly house. However, shoot length was found maximum in P22 under protected while under open field condition, it was found maximum in M111rootstsock. And survival per cent was found maximum under M9 rootstock. The polyhouse protection during the initial growth phase can significantly accelerate the production of vigorous, high quality rootstock saplings in such shorter timeframe than open field cultivation, offering a scale strategy for horticultural expansion in Ladakh’s harsh environment.

Keywords: Climate change, Apple, Rootstock, Cold arid-region, Polyhouse

**Introduction**

“The high-density planting allows an increase in fruit yield per area in the initial years of production and a reduction in the payback period despite the higher cost of implementing the orchards. Therefore, it has been a trend to enhance the production system” (Gonzatto et al., 2022). The basics of a productive and healthy orchard are the rootstocks that provide anchorage, water and nutrients essential to the above-ground portions of the trees. Thus, rootstock play a crucial role in determining productive and healthy orchard efficiency in fruit crops by directly influencing on the production of flower and fruits setting. “Dwarfing is an important agricultural trait for intensive cultivation and effective orchard management in modern fruit orchards. Commercial citrus production relies on grafting with rootstocks that reduce tree vigor to control plant height. Citrus growers all over the world have been attracted to dwarfing trees because of their potential for higher planting density, increased productivity, easy harvest, pruning, and efficient spraying. Dwarfing rootstocks can be used to achieve high density” (Hayat et al., 2022). The global adoption of dwarfing rootstocks in apple orchards has led to enhanced production efficiency, reduced input costs and improved apple quality (Robinson et al., 1991, 1997; Sansavini et al., 1981). However, till now farmer in ladakh follows a traditional system due to which could not able to achieve desired levels of potential yield as large tree provide low yield per unit area. Moreover, there is no any well-established orchard of fruit crops due to small and marginal land holding. Hence, need a new and effective technology which can improve the productivity, profitability, and sustainability of our major farming systems per unit are and the concept of high-density planting using dwarf rootstock has given trust.

The Department of Horticulture has been procuring non-traditional apple cultivars grafted onto dwarfing rootstocks prior to final road closures, without assessing their graft‑compatibility or adaptation to Ladakh’s cold-arid climate. Consequently, high mortality rates have been observed in farmers’ fields. The basics of a productive and healthy orchard are the rootstocks that provide anchorage, water and nutrients essential to the above-ground portions of the trees. Thus, rootstock play a crucial role in determining productive and healthy orchard efficiency in fruit crops by directly influencing on the production of flowers and fruits setting. Although protected cultivation can extend the growing season by preventing frost and maintaining warmer nocturnal temperatures, there is a lack of region-specific research identifying suitable dwarfing rootstocks for Ladakh’s extreme environment. Keeping in view of above facts and lacking research finding on promising dwarfing rootstock of apple under cold arid region, an attempt was made to find out the performance dwarfing four rootstock (M-9, MM-111, MM-106 and P-22) of apple under two growing conditions viz. open field and hi-tech polyhouse conditions in cold desert region of Ladakh.

**Materials and Methods**

The experiment was conducted under open field and hi-tech polyhouse conditions at Krishi Vigyan Kendra Kargil-, SKUAST-K Kargil Ladakh, during 2020-21, the cold arid region, geographically located between 32o5′ to 36o north latitude and 75o15′ to 80o15′ east longitude. The climate of the area is mainly characterized by low temperatures during winter and moderate to medium high temperatures during growing season. Four rootstock viz., M-9, MM-111, MM-106 and P-22 were procure from CITH Srinagar, Kashmir in advance before closure of national highway NH-1D in November, store in an underground level pit during winter. The saplings were dugout in the month of March when the temperature is favorable, planted both in open field as well as under hi-tech polyhouse. The design of the experiment was a factorial Randomized Block Design with four replications. Individual data at each treatment, representing a combination of rootstock and environmental condition, was replicated four times to ensure the reliability and accuracy of the results. Data from the observation were also subjected to analysis of variance (ANOVA) to compare the means of the different rootstock and different environmental conditions for each parameter. Statistical significance was determined at a 5% level (p ≤ 0.05).

**Results & Discussion:**

**Plant Height**

The data presented in the Table 1 showed that among all the rootstocks, significantly maximum plant height was observed in M111(68.88 cm) compare to other of rootstock and in case of condition, polyhouse’s rootstock M111(66.64 cm) found to attain maximum plant height compare open conditions. Interaction effect showed that M111 raised under a polyhouse took significantly highest plant height (66.64 cm). Similarly, Singh *et al.* (2004) studied the growth performance of rough lemon seedlings under screen house conditions and observed that seedlings grown under screen house obtained more plant height as compared to the seedling grown under open field conditions. This might be due to that polyhouse received prevailing fairly long periods of favorable temperature and relative humidity for earlier sprouting and thus retain good height.

**No. of shoot**

In this existing analysis, among different rootstock M111 has been recorded with maximum number of shoot (8.63) and under environmental condition maximum number of shoot was recorded in rootstock kept under polyhouse (7.94). With reference to the interaction effect M111 kept under poly house condition (9.75) showed more number of shoot. This might be due to their vigorous growth behavior. However, the slow growth growth habit of M9 and P22 considerably influences the number of shoot. Earlier sprouting might be due to creation of high humidity and reduced the desiccation of active tissue of the rootstock in polyhouse as compared to open condition. The similar kinds of findings were recorded by Jalal *et al*. (2018) in aonla and Patel *et al*. (2007) in mandarin.

**Shoot length**

In the present study, among all the rootstock maximum shoot length were recorded in P22 (15.94 cm) and among different environmental condition, the rootstock planted under polyhouse condition has been recorded with maximum length of shoot (13.69). While in interaction effect P22 rootstock kept under polyhouse condition length of shoot (17.00). It might be linked to rootstock’s genetic performance as well as prevailing fairly long periods of favourable temperature and relative humidity within polyhouse, which encouraged for early sprouting with increased shoot length. The similar kinds of findings were recorded by Gotur *et al*. (2017b), Patel *et al*. (2007) in mandarin and Sivudu *et al*. (2014) in mango.

**Stock girth**

Data regarding stock girth mentioned in Table 2 suggested that M111 recorded maximum (1.97 cm) stock girth and in condition polyhouse recorded significantly highest stock girth (1.52 cm). With respect to interaction effect maximum stock girth was noticed in rootstock M111 planted under polyhouse condition. The variation in stock girth in different rootstocks may be due to the difference in genetic behaviour of each genotype, the right growing conditions and the climatic factors that results in maximum no of shoots production, which are all possible explanation for steadily increasing in stock girth. Differences in vegetative growth pattern of rootstocks might also have contributed to varied stock girth in these stocks.

**Survival per cent**

The performance was better under protected than compared to open conditions (Table 2), as survival percentage is found to be highest in M9 rootstock (70.87 %) and the polyhouse condition recorded significantly highest survival per cent compared to open conditions with 86.44 % and 52.15 % respectively. However interaction effect showed maximum survival per cent in M9 rootstock with 87.25% followed by P22 rootstock with 87.00 %. This might be due to varietal genetic character, optimal temperature and humidity in polyhouse, which aids in achieving a higher survival per cent as compare to other growing environment. The present studys were supported by Visen et al. (2010), Mamta et al. (2016 in guava, Raghavendra et al.(2011) in wood apple, Kamble et al (2025) in guava

**Conclusion**

In this study, rootstock planted within a polyhouse exhibited significantly higher growth indices and survival percentages compared to those in open conditions; the controlled micro environment of optimal temperature and relative humidity, especially during the freezing initial phase outdoors, promoted superior growth and viability. In the extreme cold desert of ladakh, where winter temperature can drop below -30oC, diurnal temperature variation is intense, wind speeds frequently reach 45-60mph, and the growing season is confined to merely 2-5 month, early stage poly house cultivation proved especially valuable.

The polyhouse protection during the initial growth phase can significantly accelerate the production of vigorous, high-quality rootstock saplings in such shorter timeframe than open field cultivation, offering a scale strategy for horticultural expansion in Ladakh’s harsh environment.

It is concludedthat rootstocks planted directly under protected structure were found with more survival percentages with 99 per cent while under open condition it was found with 50% survival per cent. Thus, in cold arid region of Ladakh, after procurement of planting materials from outside of state, it is better to transplant directly in green house (hi-tech or polycarbonate) than to store in pit.

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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Table1. Influence of environmental condition on different growth parameter (Plant Height, No. of Shoot and Shoot length) of apple rootstocks

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **PH (cm)** | | | **N.S** | | | **S.L (cm)** | | |
| **Rootstock** | **Open** | **protected** | **Mean** | **Open** | **protected** | **Mean** | **Open** | **protected** | **Mean** |
| **M9** | 60.25 | 65.63 | 62.94 | 5.00 | 7.50 | 6.25 | 9.37 | 10.37 | 9.87 |
| **M106** | 63.00 | 66.31 | 64.66 | 6.00 | 8.25 | 7.13 | 9.69 | 16.50 | 13.09 |
| **M111** | 64.75 | 68.88 | 66.81 | 7.50 | 9.75 | 8.63 | 15.88 | 10.87 | 13.37 |
| **P22** | 60.25 | 65.75 | 63.00 | 5.25 | 6.25 | 5.75 | 14.88 | 17.00 | 15.94 |
| **Mean** | 62.06 | 66.641 |  | 5.94 | 7.94 |  | 12.45 | 13.69 |  |
|  | **C.D at 5%** | **SE d+** | **SE m+** | **C.D at 5%** | **SE d+** | **SE m+** | **C.D at 5%** | **SE d m+** | **SE m+** |
| **R** | 1.49 | 0.71 | 0.50 | 1.38 | 0.66 | 0.46 | 0.59 | 0.28 | 0.20 |
| **C** | 1.06 | 0.50 | 0.36 | 0.97 | 0.46 | 0.33 | 0.42 | 0.20 | 0.14 |
| **R x C** | N/A | 1.01 | 0.71 | N/A | 0.93 | 0.66 | 0.84 | 0.40 | 0.28 |

PH: Plant Height; NS: No. of shoot; SL: Shoot length; R: Rootstock; C: Condition

Table2. Influence of environmental condition on different growth parameter (Stock girth and Survival per cent) of apple rootstocks

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **S G (cm)** | | | **S %** | | |
| **Rootstock** | **Open** | **protected** | **Mean** | **Open** | **protected** | **Mean** |
| **M9** | 0.89 | 0.95 | 0.92 | 54.50 | 87.25 | 70.87 |
| **M106** | 1.50 | 2.02 | 1.76 | 51.75 | 86.50 | 69.12 |
| **M111** | 1.81 | 2.14 | 1.97 | 50.75 | 85.00 | 67.87 |
| **P22** | 0.87 | 0.95 | 0.91 | 51.50 | 87.00 | 69.25 |
| **Mean** | 1.27 | 1.52 |  | 52.15 | 86.44 |  |
|  | **C.D at 5%** | **SE d+** | **SE m+** | **C.D at 5%** | **SE d m+** | **SE m+** |
| **R** | 0.24 | 0.12 | 0.08 | N/A | 10.00 | 0.71 |
| **C** | 0.17 | 0.08 | 0.06 | 1.48 | 0.71 | 0.50 |
| **R x C** | N/A | 0.16 | 0.12 | N/A | 1.41 | 10.00 |

SG: Stock Girth; S %: Survival per cent; R: Rootstock; C: Condition