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SEED GERMINATION AND VIGOUR EVALUATION OF TOMATO, BRINJAL AND CHILLI FOR OPTIMIZED GRAFTING SCHEDULES

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ABSTRACT

Seed germination and seedling vigour play a pivotal role in determining the success of grafting in solanaceous crops. The present investigation was carried out during Spring–Summer, 2025 at the Centre of Excellence, Mulugu, Siddipet, Telangana, to evaluate germination behaviour and vigour indices in nine genotypes comprising three (3) unique lines used as rootstocks one from each of tomato (MHTO101), brinjal (*Solanum torvum* Sw.) and chilli (EC-402105) and six (6) varieties two from each tomato (Kashi Adarsh and Saaho), brinjal (Shyamala and Nano) and chilli (Byadgi Kaddi and EZ-H 1810) used as scions for developing 18 graft combinations in completely randomized design with three replications. The study assessed days taken for germination, germination percentage (%), days to reach grafting stage and seed vigour parameters including seed vigour index I, seed vigour index II, germination energy (%), mean germination time and germination rate index. The results revealed significant genotypic variation for all parameters. Among rootstocks, tomato MHTO101 (tomato) showed superior performance. Whereas, *Solanum torvum* Sw. (brinjal) exhibited the higher Seed Vigour Index I (1388.88) and II (63.83) values, indicating superior seedling growth and biomass accumulation. Similarly, scions Saaho (tomato), Kashi Adarsh (tomato) and Nano (brinjal) exhibited early germination (4.00–5.50 days), high germination (94.50–97.50%). Nano (brinjal) displayed the higher Seed Vigour Index I values (2468.18) and II (113.47) values and Germination Energy (86.20%).

Key words: Tomato, Brinjal, Chilli, Seed germination, Vigour indices, Grafting, Rootstock, Scion

Introduction

Seed germination is a critical physiological process that determines the establishment, growth, and performance of crops. In solanaceous vegetables such as tomato (*Solanum lycopersicum*), brinjal (*Solanum melongena*) and chilli (*Capsicum annuum*), uniform and rapid seed germination is particularly important, as these crops are often grafted to overcome biotic and abiotic stresses and to ensure higher productivity under intensive cultivation (Gisbert *et al*., 2011; Kumar *et al*., 2017). The success of grafting largely depends on the synchronization of rootstock and scion seedlings, which in turn is influenced by their germination behavior and vigor potential (Lee *et al*., 2010; Dhivya, 2013).

Traditional germination parameters such as days to germination, seed germination percentage and days to reach grafting stage provide essential information about seedling readiness, but they often fail to capture the complete dynamics of germination (Rathod, 2017; Musa *et al*., 2020). For instance, rootstocks like *Solanum torvum*, widely used in brinjal grafting are known to exhibit slow and erratic germination, requiring special pre-treatments and staggered sowing (Rajatha *et al*., 2018; Yashwanth, 2021). On the other hand, tomato genotypes and cultivated brinjal varieties often germinate rapidly, making them more suitable for synchronized nursery management (Sindhuja *et al*., 2023). Thus, an in-depth evaluation of seed germination traits across different genotypes is essential for optimizing grafting practices.

In addition to conventional germination parameters, vigour indices such as Seed Vigour Index I, Seed Vigour Index II, Mean Germination Time, Germination Energy (%) and Germination Rate Index provide comprehensive insights into seedling performance (Abdul-Baki and Anderson, 1973; Maguire, 1962; Czabator, 1962; Ellis and Roberts, 1981). These indices not only measure the speed and uniformity of germination but also reflect the ability of seedlings to establish successfully under both nursery and field conditions. High vigour is particularly important in grafting, as it ensures uniform stem diameters, rapid growth and higher graft survival (Pogonyi *et al*., 2005; Schwarz *et al*., 2010).

Despite the significance of these parameters, limited research has been conducted to comprehensively assess seed germination and vigour traits in multiple solanaceous rootstocks and scions under a single study. Most earlier reports have focused either on grafting success or individual species, without integrating seed physiology aspects critical to nursery scheduling. Therefore, the present investigation was undertaken to evaluate seed germination behavior and vigour parameters in selected genotypes of tomato, brinjal and chilli, with the objective of identifying superior rootstocks and scions for synchronized grafting and efficient nursery management.

Materials and Methods

The experiment was conducted at the Hi-Tech Nursery, Centre of Excellence, Mulugu, Siddipet District, Telangana, during the *Spring–Summer* season of 2025, in a Completely Randomized Design (CRD) with 9 treatments replicated thrice. Three (3) unique lines were used as rootstocks one from each of tomato (MHTO101), brinjal (*Solanum torvum* Swartz) and chilli (EC-402105) and six (6) varieties two from each tomato (Kashi Adarsh and Saaho), brinjal (Shyamala and Nano) and chilli (Byadgi Kaddi and EZ-H 1810) were used as scions.

To overcome dormancy, *Solanum torvum* Sw. (brinjal) seeds were pre-soaked in GA_3 solution (2000 ppm) for 24 hours before sowing (Sindhuja *et al*., 2023). Remaining were sown without any pre-treatment. All seeds were sown in 98-celled portrays filled with sterilized cocopeat medium. Seedlings were maintained under controlled nursery conditions with mist irrigation and prophylactic plant protection measures were undertaken timely. Observations recorded on seed parameters included days taken for germination, seed germination percentage (%) and days taken to reach the grafting stage. In addition, seed vigour parameters were assessed including Germination Energy (%), Mean Germination Time, Germination Rate Index, Seed Vigour Index I and Seed Vigour Index II.

Days taken for seed germination was assessed by considering the number of days taken from sowing to the first seed germination appearance of both scions and rootstocks was recorded in each replication. To calculate seed germination percentage (%), one hundred seeds were planted in protrays filled with coco-peat. By visually observing and counting the emergence of seedlings, the observation was documented.

$$\text{Germination (\%)} = \frac{n}{N} \times 100$$

Where,

n = number of seeds germinated,

N = total number of seed sown in each replication.

Days taken to reach the grafting stage arrived by considering the total number of days from seeding to reaching the ideal stem thickness for grafting in both scions and rootstocks was noted in each replication. While, germination energy (%) measured by calculating the percentage of normal seedlings germinated on the nth day after sowing was recorded for both scions and rootstocks in each replication (Czabator, 1962).

$$\text{Germination Energy (\%)} = \frac{n}{N} \times 100$$

Where,

n = number of seeds germinated on the nth day,

N = total number of seeds sown in each replication.

The mean germination time was determined by recording the number of seeds germinated each day for both scions and rootstocks until germination was completed in all replications. The mean germination time indicated the average time required for seeds to germinate (Ellis and Roberts, 1981).

$$MGT = \frac{\sum(ni \times di)}{\sum ni}$$

Where,

ni = number of seeds germinated on day i,

di = number of days from sowing.

The germination rate index was calculated by recording the number of seeds germinated each day from the date of sowing until no further germination occurred for both scions and rootstocks in each replication. The germination rate index, represented the speed and uniformity of germination (Maguire, 1962).

$$GRI = \sum \frac{Gi}{Di}$$

Where,

Gi = cumulative germination (%) up to day i,

Di = day of germination count.

At the end of the germination test (30 days), ten normal seedlings from each replication were randomly selected. The root and shoot lengths and dry weights of each seedling were measured and averaged. The Seed Vigour Index I was calculated by multiplying the germination percentage with the mean seedling length and Seed Vigour Index II was calculated by multiplying the germination percentage with the mean seedling dry weight, following the method described by Abdul-Baki and Anderson (1973).

$$\text{SVI-I} = \text{Germination (\%)} \times \text{Mean seedling length (cm)}$$

$$\text{SVI-II} = \text{Germination (\%)} \times \text{Mean seedling dry weight (g)}$$

The statistical assessment was carried by using OPSTAT, an open-source agricultural data analysis tool provided by CCSHAU, Hissar. The data pertaining to all characters studied under both the experiments independently were subjected to the statistical analysis given by Panse and Sukhatme (1967) for Completely Randomized Design (CRD). The treatment differences were tested by 'F' test of significance based on the null hypothesis. The critical difference was calculated when the difference between the treatments was found significant by 'F' test. All data analysed and results was presented and discussed at a probability level of 5 per cent.

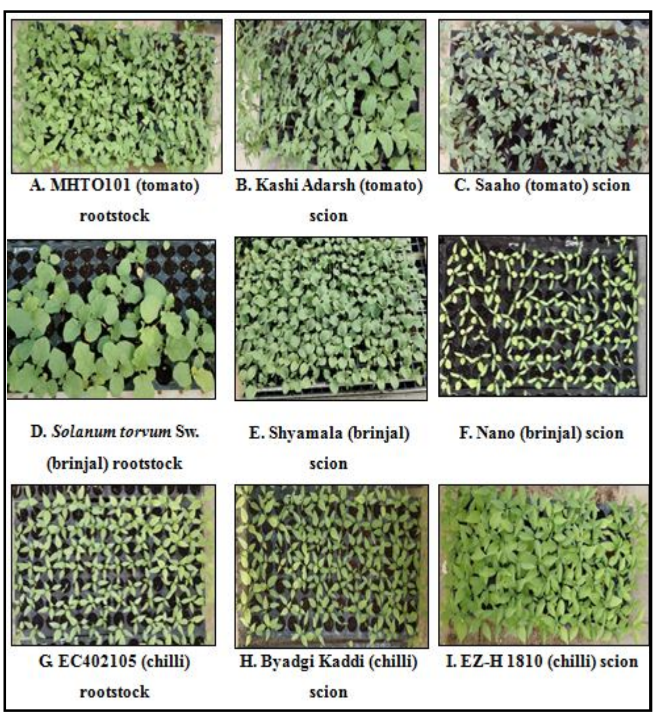

Plate 1: Protrays of planting material- rootstocks and scions used in experiment.

Table 1: Performance of rootstocks and scions of tomato, brinjal and chilli for seed germination related parameters.

Planting material	**DTG**	**SG**	**DGS**
MHTO101 (Tomato)	4.50	95.50	29.50
Solanum torvum Sw. (Brinjal)	11.50	54.00	67.50
EC402105 (Chilli)	6.50	83.50	44.00
Kashi Adarsh (Tomato)	5.50	94.50	32.00
Saaho (Tomato)	4.00	97.50	30.50
Shyamala (Brinjal)	15.50	90.00	40.50
Nano (Brinjal)	4.50	96.00	30.50
Byadgi Kaddi (Chilli)	7.50	91.00	43.50
EZ-H-1810 (Chilli)	7.50	92.50	42.50
C.D. at 5%	**1.53**	**2.48**	**2.09**
SE(m)±	**0.47**	**0.76**	**0.65**
C.V. (%)	**8.96**	**1.22**	**2.28**

DTG: Days taken for germination; **SG:** Seed germination (%); **DGS:** Days taken to reach the grafting stage

Results and Discussion

Seed germination related data presented in Table 1 reveals significant differences in germination times among various rootstocks and scions. Among the rootstocks, MHTO101 (tomato) exhibited the fastest germination at 4.50 days, followed by EC-402105 (chilli) at 6.50 days, while *Solanum torvum* Sw. (brinjal) took the longest at 11.50 days. Similarly, among the scions, Saaho (tomato) germinated in 4.00 days, Nano (brinjal) in 4.50 days and Kashi Adarsh (tomato) in 5.50 days, whereas Byadgi Kaddi (chilli) and EZ-H 1810 (chilli) both required 7.50 days and Shyamala (brinjal) took the longest at 15.50 days. For effective optimization of the sowing schedule in this study, recording the number of days required for seed germination in both rootstocks and scions is essential. Adjusting the planting dates accordingly ensures the production of scion and rootstock seedlings with compatible stem diameters, facilitating successful grafting. Comparable findings have been reported by Dhivya (2013), Rathod (2017), Rajatha *et al*., (2018), Musa *et al*., (2020), Yashwanth (2021), Sindhuja *et al*., (2023) and Rajesh *et al*., (2024).

The seed germination (%) results, which showed significant differences between the rootstocks and scions (Table 1 and Fig. 1). Among the rootstocks, MHTO101 (tomato) recorded the highest germination percentage (95.50%), followed by EC-402105 (chilli) (83.50%), whereas *Solanum torvum* Sw. (brinjal) exhibited the lowest germination percentage (54.00%). Among the scions, Saaho (tomato), Nano (brinjal) and Kashi Adarsh (tomato) showed the highest germination rates (97.50%, 96.00% and 94.50%, respectively) followed by EZ-H 1810 (chilli) and Byadgi Kaddi (chilli) (92.50% and

Table 2: Performance of rootstocks and scions of tomato, brinjal and chilli for seed vigour related parameters.

Planting material	Seed Vigour Index I	Seed Vigour Index II
MHTO101 (Tomato)	1143.14	58.45
Solanum torvum Sw. (Brinjal)	1388.88	63.83
EC402105 (Chilli)	1244.15	51.35
Kashi Adarsh (Tomato)	1125.18	57.83
Saaho (Tomato)	1174.88	73.03
Shyamala (Brinjal)	2314.80	104.04
Nano (Brinjal)	2468.18	113.47
Byadgi Kaddi (Chilli)	1355.90	54.15
EZ-H-1810 (Chilli)	1253.37	58.74
C.D. at 5%	**54.938**	**11.896**
SE(m)±	**16.934**	**3.667**
C.V. (%)	**1.600**	**7.362**

91.00%, respectively), while Shyamala (brinjal) had the lowest germination percentage (90.00%) among the scions. These differences may be attributed to inherent genetic factors, seed maturity and viability, as well as seed coat hardness, dormancy, and pre-sowing treatments. Similar trends have been reported in solanaceous crops, where high-vigour seeds consistently produced better germination, while slower-germinating species benefited from treatments such as GA_3 soaking or priming to improve uniformity. Similar findings have been reported by Dhivya (2013), Rathod (2017), Yashwanth (2021) and Sindhuja *et al.*, (2023).

The number of days required to reach the grafting stage related data presented in Table 1 and Fig. 2 varied significantly among rootstocks and scions. In rootstocks MHTO101 (tomato) required the minimum time (29.50 days) to reach the grafting stage followed by EC-402105 (chilli) (44.00 days), whereas *Solanum torvum* Sw. (brinjal) took the longest (67.50 days). Among scions, Saaho (tomato), Nano (brinjal) and Kashi Adarsh (tomato) attained the grafting stage in the shortest time (30.50 days, 30.50 days and 32.00 days, respectively), while

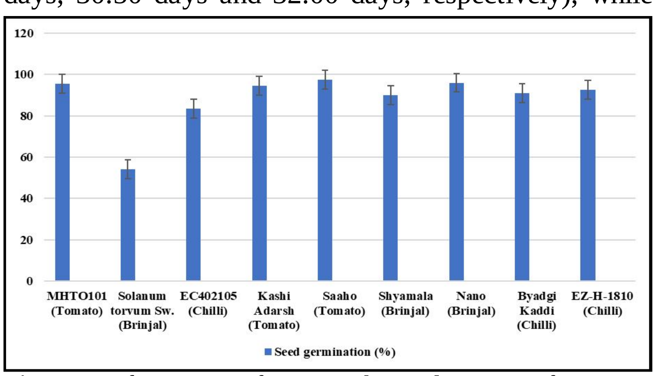

Fig. 1: Performance of rootstocks and scions of tomato, brinjal and chilli for seed germination (%).

Byadgi Kaddi (chilli) (43.50 days), EZ-H 1810 (chilli) (42.50 days) and Shyamala (brinjal) (40.50 days) required comparatively more days to reach the grafting stage. These variations are likely influenced by inherent genetic differences affecting growth rate, stem thickness and seedling vigour. Faster-growing seedlings attain the optimal stem diameter for grafting sooner, which is essential for successful graft unions and uniformity in grafted plants. Similar patterns have been observed in solanaceous crops, where rootstock and scion growth rates determined the appropriate timing for grafting by Dhivya (2013), Rathod (2017), Yashwanth (2021) and Rajesh *et al.*, (2024).

Significant differences were found in seed vigour index-I between the studied rootstocks and scions (Table 2). The rootstock with the highest seed vigour index-I was *Solanum torvum* Sw. (brinjal) (1388.88), followed by EC-402105 (chilli) (1244.15) and the lowest was MHTO101 (tomato) (1143.14). On the other hand, among scions, Nano (brinjal) had the highest (2468.18), which was comparable to Shyamala (brinjal) (2314.80). Saaho (tomato) (1174.88) and Kashi Adarsh (tomato) (1125.18) had the lowest values. Seed Vigour Index-I indicates genotypic variation in seedling growth potential. Rootstocks and scions of brinjal and *Solanum torvum* Sw. (brinjal) typically exhibit higher vigour, whereas tomato genotypes show comparatively lower seedling performance, emphasizing the need to select vigorous material for effective grafting. Similar observations have been reported by Abdul-Baki & Anderson (1973), Nerson (2007) and Kumar *et al.*, (2017).

The seed vigour index-II results, which showed significant differences between the tested rootstocks and scions (Table 2 and Fig. 2). The rootstock with the highest seed vigour index-II was *Solanum torvum* Sw. (brinjal) (63.83), followed by MHTO101 (tomato) (58.45) and EC-402105 (chilli) (51.35). Nano (brinjal) (113.47) was noticeably higher and Shyamala (brinjal) (104.04) was

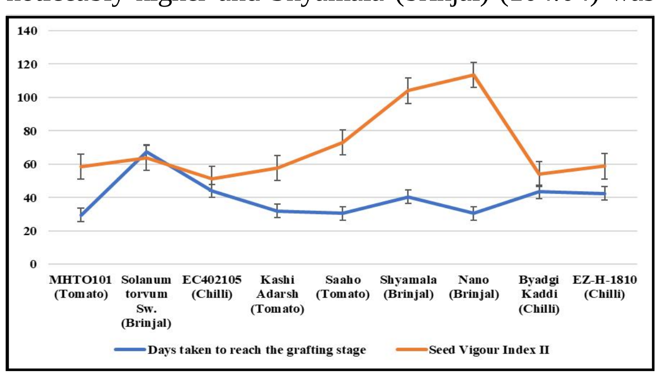

Fig. 2: Performance of rootstocks and scions of tomato, brinjal and chilli for days taken to reach the grafting stage and seed vigour index II related parameters.

Table 3: Performance of rootstocks and scions of tomato, brinjal and chilli for germination energy (%), mean germination time and germination rate index related parameters.

Planting material	GE	MGT	GRI
MHTO101 (Tomato)	74.16	18.78	17.80
Solanum torvum Sw. (Brinjal)	27.86	4.58	7.80
EC402105 (Chilli)	67.00	19.15	15.46
Kashi Adarsh (Tomato)	79.60	18.95	15.92
Saaho (Tomato)	77.00	19.37	15.40
Shyamala (Brinjal)	58.40	18.53	11.68
Nano (Brinjal)	86.20	20.06	17.24
Byadgi Kaddi (Chilli)	81.20	19.83	16.24
EZ-H-1810 (Chilli)	82.00	19.69	16.40
C.D. at 5%	**11.747**	**3.277**	**2.179**
SE(m)±	**3.621**	**1.010**	**0.672**
C.V. (%)	**7.276**	**8.088**	**6.383**

GE: Germination Energy (%); **MGT:** Mean Germination Time; **GRI:** Germination Rate Index

next. Byadgi Kaddi (Chilli) had the lowest (54.15), followed by Kashi Adarsh (tomato) (57.83) and EZ-H 1810 (chilli) (58.74). Seed Vigour Index-II reflects genotypic variation in seedling biomass and establishment potential. Rootstocks and scions of brinjal and *Solanum torvum* Sw. (brinjal) generally demonstrate higher vigour, whereas tomato and chilli genotypes exhibit lower seedling growth, highlighting the importance of selecting vigorous material for successful grafting. Comparable observations have been reported by Abdul-Baki & Anderson (1973), Nerson (2007) and Kumar *et al*., (2017).

The germination energy (%) data, which varied significantly between the evaluated rootstocks and scions (Table 3 and Fig. 3). Among the rootstocks, MHTO101 (tomato) had the highest germination energy (74.16%), followed by EC-402105 (chilli) at (67.00%) and *Solanum torvum* Sw. (brinjal) (27.86%). Among the scions, Nano (brinjal) had the highest (86.20%), equivalent to EZ-H 1810 (chilli) (82.00%), Byadgi Kaddi (chilli) (81.20%) and Kashi Adarsh (tomato) (79.60%). While, Shyamala (brinjal) had the lowest germination energy (58.40%). Germination energy reflects seed vigour, uniformity and the ability to produce seedlings rapidly (Ranal & Santana, 2006). Genotypic variation strongly affects germination energy (%), with tomato and chilli seeds typically germinating faster and more uniformly, while brinjal seeds may germinate more slowly due to dormancy or delayed metabolic activity (Kumar *et al*., 2017; Demir *et al*., 2008). High germination energy (%) is essential for synchronized seedling production in grafting programs, ensuring timely and robust establishment. Similar observations have been reported by Nerson (2007) and Basavaraj *et al*., (2016).

The mean germination time results revealed notable differences between the assessed rootstocks and scions (Table 3 and Fig. 3). In terms of rootstocks, EC-402105 (chilli) had the greatest mean germination time (19.15 days), followed by MHTO101 (tomato) (18.78 days), while *Solanum torvum* Sw. (brinjal) had the smallest mean germination time (4.58 days). Among scions, Shyamala (brinjal) had the lowest (18.53 days), which was comparable to that of Kashi Adarsh (18.95 days), Saaho (19.37 days), EZ-H 1810 (19.69 days) and Byadgi Kaddi (19.83 days). The greatest was 20.06 days for Nano (brinjal). Mean Germination Time indicates genotypic variation in seedling emergence, with shorter mean germination time associated with higher vigour and faster establishment. Factors such as seed coat properties and dormancy influence mean germination time, which is important for synchronized seedling production and successful grafting. Comparable findings have been reported by Ranal & Santana (2006), Basavaraj *et al*., (2016) and Kumar *et al*., (2017).

The evaluated rootstocks and scions showed significant variations according to the results of the germination rate index (Table 3 and Fig. 3). The rootstock with the highest germination rate Index was MHTO101 (tomato) (17.80), followed by EC-402105 (chilli) (15.46), while *Solanum torvum* Sw. (brinjal) (7.80) had the lowest. The scions, Nano (brinjal) had the highest germination rate index (17.24), which was comparable to EZ-H 1810 (chilli) (16.40), Byadgi Kaddi (chilli) (16.24) and Kashi Adarsh (tomato) (15.92). Shyamala (brinjal) had the lowest germination rate index (11.68). Genotypic variation strongly affects germination rate index, with tomato and chilli typically showing faster germination, while brinjal may germinate more slowly due to dormancy or reduced metabolic activity (Demir *et al*., 2008 and Kumar *et al*., 2017). Higher germination rate index promotes rapid and uniform seedling establishment, which

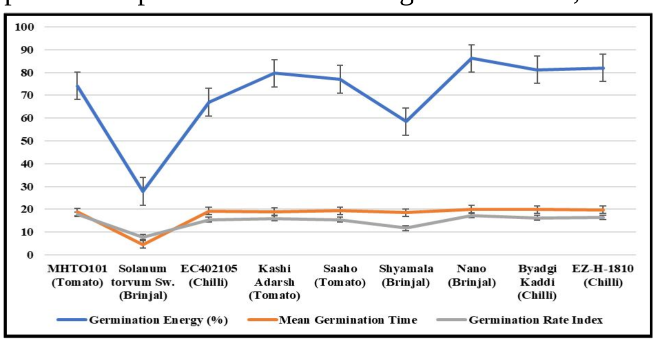

Fig. 3: Performance of rootstocks and scions of tomato, brinjal and chilli for germination energy (%), mean germination time and germination rate index related parameters.

is crucial for efficient grafting and early growth. Similar trends have been reported by Nerson (2007) and Basavaraj *et al*., (2016).

Conclusion

The present study demonstrated significant variation in seed germination behaviour and vigour indices among tomato, brinjal and chilli genotypes used as rootstocks and scions for grafting. MHTO101 (tomato), Saaho (tomato), Kashi Adarsh (tomato) and Nano (brinjal) consistently exhibited early germination, higher germination percentages, shorter mean germination time and superior vigour indices (Seed Vigour Index-I and II), making them highly suitable for commercial grafting. Chilli genotypes (EC-402105, EZ-H 1810 and Byadgi Kaddi) showed moderate germination and vigour, requiring careful nursery scheduling to synchronize with faster-growing scions. In contrast, *Solanum torvum* Sw. (brinjal) displayed delayed and poor germination, higher mean germination time and lower vigour indices, highlighting the need for pre-sowing treatments and staggered sowing to improve synchronization.

Overall, the results emphasize that genotype-specific differences in germination and vigour must be carefully considered while planning sowing schedules for grafted seedling production. Prioritizing high-vigour genotypes such as MHTO101 (tomato), Saaho (tomato), Kashi Adarsh (tomato) and Nano (brinjal), while adopting appropriate management practices for chilli and *Solanum torvum* Sw. (brinjal), will ensure efficient nursery management, improved grafting success and a steady supply of quality grafted plants for commercial cultivation.

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