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Different pre-sowing treatments intensify the germination process and the seedling growth of fruit crops

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Abstract
Pre-sowing treatments are critical for increasing seed germination by dealing with dormancy, increasing water intake, and boosting nutrient absorption. Treatments prior to sowing interrupt seed dormancy which results in fast and uniform germination. Pre-sowing treatments stimulate robust seedling emergence by improving the absorption of water and nutrient uptake, resulting in stronger plants with faster early development. Seed germination is the active developing of an embryo that leads to the emergence of a new plant. Even under optimum circumstances, many fruit crop seeds fail to germinate. Seed dormancy can occur due to a hard seed coat, germination stratification, water immersion, inhibitors, or poor embryo development. The seeds may require particular treatments such as scarification, growth regulators, stratification and chemical treatments to overcome dormancy of the seeds. Pre-sowing treatments focused at decreasing disease and pest incidence help to produce healthier seedlings, reducing losses and assuring crop establishment. Also, pre-sowing treatments help seed to adapt environmental problems, improving resilience and the chance of successful germination and crop growth, emphasising their critical role in agricultural productivity and sustainability. This review summarises the impact of pre-sowing seed treatment on seed germination and seedling growth for several fruit crops.

Keywords: Gibberellic acid, dormancy, seedlings, fruit crops, germination

Introduction

Germination of seeds is a fundamental step in plant development cycles and plays a critical role in the facility, naturalisation, and increase of their populations (Donohue *et al*., 2010) [8]. Germination is the mechanism by which a seed grows into an entirely new plant and is crucial important in the production of fruit crops (Wolny *et al*., 2018) [30]. It is the initial stage in the developmental process of fruit-bearing plants by establishing the path for their maturation, development, and eventual fruit production. Understanding the significance of germination in fruit plants is critical for improving agricultural techniques and guaranteeing long-term production (Carrera-Castaño *et al*., 2020) [5]. Germination also effects seedling vigour, which has a direct impact on fruit crop health and yield. Vigorous seedlings grow rapidly, have strong roots, and are more resistant to both abiotic and biotic stresses. Growers could increase fruit crop tolerance to diseases, pests, and environmental difficulties by enhancing seedling health through optimal germination conditions. The successful plant establishment requires rapid germination as well as the emergence of healthy seedlings. Different methods have been tried to promote seed germination and good seedling development including pre-sowing seed treatment, seed priming and seed soaking. Seed treatment improves germination, seedling development, and yield in both normal and stressed conditions. Research suggests that pre-sowing/soaking and seed hardening (hydration/dehydration) treatments using chemicals may enhance seed performance (Siddique and Kumar, 2018) [25].

The majority of horticultural crops are propagated via seeds, particularly fruit crops like papaya, phalsa, Kagzi lime, and karonda. Raising a plant from seeds requires an extensive knowledge of seed viability, storage, planting timing, germination parameters, and seedling care. Poor seed germination is a key limiting issue for many important fruit crops. It is speculated that a significant number of germination inhibitors, such as coumarin, benzoic acid, jasmonic, cinnamic acid, naringenin, and abscisic acid (ABA), are present in seed coats (testa) of many fruit species, preventing their seeds from germinating. Seed germination failure may be caused by hard seed coat or dormancy. Pre-sowing treatments are known to improve seedling germination along with growth in a variety of fruit species. Pre-treating fruit crop seeds, such as scarification, stratification or soaking in hot or cold water treatment, GA_3 and acid treatments are crucial to maximising seed coat impermeability and improving germination.

Pre-sowing treatments

GA_3 treatment

Gibberellic acid (GA_3) is an essential plant growth regulator that promotes early plant development and seed germination. GA_3 affects a number of physiological mechanisms in seeds and seedlings when treated as a pre-sowing seed treatment, which promotes improved germination and vigorous early development. Many seeds possess dormant mechanisms that inhibit germination even in the presence of ideal conditions for growth. GA_3 breaks dormancy by encouraging the production of enzymes that break down substances that cause dormancy, such abscisic acid (ABA) (Gupta and Chakrabarty, 2013) [11]. The seed can sprout more easily as a result of the breaking of dormancy. GA_3 treatment increases the activity of important enzymes including proteases and α-amylase that are involved within the seeds were activated (Du *et al*., 2022) [9]. These enzymes provide energy and the building blocks needed for seedling development during germination by dissolving complex proteins and carbohydrates into simpler forms. The increased amino acids and soluble sugars provide an instant energy source for germination and early seedling development. Simultaneously, GA_3 promotes the formation of the radicle and plumule that accelerates the emergence of seedlings by increasing the cells in the cotyledons and embryonic axis (Urbanova and Leubner-Metzger, 2016) [29]. To promote successful seedling establishment, this acceleration of cell growth is combined with the stimulation of genes that control cell wall loosening and water absorption. Furthermore, GA_3 controls hormonal interaction by connecting to cytokinins and auxins to control the formation of roots and shoots among other growth processes. GA_3 increases the seedling vigour and making them more resilient to environmental stressors by encouraging stem elongation and root development. The pre-sowing treatment of GA_3 results in enhanced crop production, rapid germination, and strong early development.

Stratification

Stratification is a pre-sowing treatment that involves exposing seeds to moist and cold conditions for a certain period of time. This treatment has significant physiological effects that improve early plant development and seed germination (Cheng *et al*., 2022) [7]. This procedure mimics the environmental conditions necessary to break seed dormancy, especially in species that have hard seed coats or have adapted to temperate climates. Low temperatures during stratification cause physiological changes in the seed such as the breakdown of substances that cause dormancy and the activation of germination-related enzymes (Nautiyal *et al*., 2023) [20]. Additionally, gibberellins necessary for germination and early development, are synthesised more readily in colder temperatures. Furthermore, the moisture delivered during stratification promotes the loosening of seed coverings and intake of water, therefore start the metabolic processes required for germination. As an outcome, stratified seeds have higher germination rates, greater seedling vigour, as well as greater uniform emergence (Yang *et al*., 2020) [31]. Also, stratification can encourage the build-up of carbohydrates along with other reserve compounds within the seed, resulting in a nutrient-rich environment that supports early seedling development. Stratification, with its capacity to break dormancy and prepare seeds for germination is a critical tool in optimising seedling establishment and crop yields, especially in fruits crop with complicated dormancy needs or under tough climatic conditions.

Mechanical scarification

Scarification is the process of weakening or modifying the seed coat in order to promote germination. Mechanical, thermal, and chemical methods are frequently used in scarification. Many plant species have seeds that are resistant to gases and water, which inhibits or delays germination. All kinds of scarification acts by accelerating the natural processes that typically allow seed coverings to be permeable to air and water. Mechanical scarification is a technique for overcoming an impermeable seed covering. Mechanical scarification involves rubbing seeds with sandpaper, abrasive grit, or shaking rapidly. Seeds can become permeable to air and water using several ways such as heating, cooling, severe temperature fluctuations, dipping in hot water, piercing the coat with a needle, and exposure to certain wavelengths (Naik and Deshpande, 2021) [19].

Acid treatment

Acid treatments can be used to remove outer layer of the seed and break dormancy of the seed. Acid treatments are frequently applied to dissolve very thick seed layers that are impermeable. The temperature and amount of time the seeds are soaked in concentrated sulfuric acid (H_2SO_4) are critical factors since seeds immersed in this solution will eventually turn into charcoal. Depending on the species, the acid should be employed at room temperature for a few minutes to many hours. In a glass, earthen, or ceramic container, the seeds should be submerged in acid. The acid should be periodically agitated with a glass rod but excessive stirring will result in the acid heating up unfavourably. As soon as the acid begins to penetrate through the seed coat, the seeds need to be taken out of the solution. After the specified amount of time has passed, the seeds should be taken out right away and properly cleaned in many changes of water to eliminate any last traces of acid. For many species, it is only possible to determine experimentally how long the acid bath will last based on the particular batch of seeds. The seeds can be planted right away or dried and kept for several months after being treated. Certain seed coat enzymes such pectinase and cellulase are employed in innovative methods to get rid of the seed coat. Moreover, chemical solvents like acetone and alcohol are employed to break the dormancy of seeds (Mousavi *et al*., 2011) [18].

Hot water treatment

Hot water soaking is the best seed treatment in terms of least amount of damage, cost, effectiveness, and application. This ancient method involves treating the seeds with hot water at a temperature that kills the pathogen without damaging the seed. It is an excellent way to deal with many seed-borne diseases and break the dormant state of seeds. Additionally, the use of hot water treatment can accelerate physiological processes in the seed, such as the activation of germination-related enzymes or the disruption of dormant mechanisms. Consequently, compared to untreated seeds, hot water treated seeds may show quicker and more consistent germination, resulting in more reliable seedling emergence. Seeds can be heat-treated using infrared or microwave radiation, immersion in hot water, exposure to vapour heat, or exposure to hot and dry air. Compared to chemical treatments, hot water treatments are a more environmentally friendly and efficient form of conventional thermo-physical plant protection for seeds and plant material (Singh *et al*., 2020) [27].

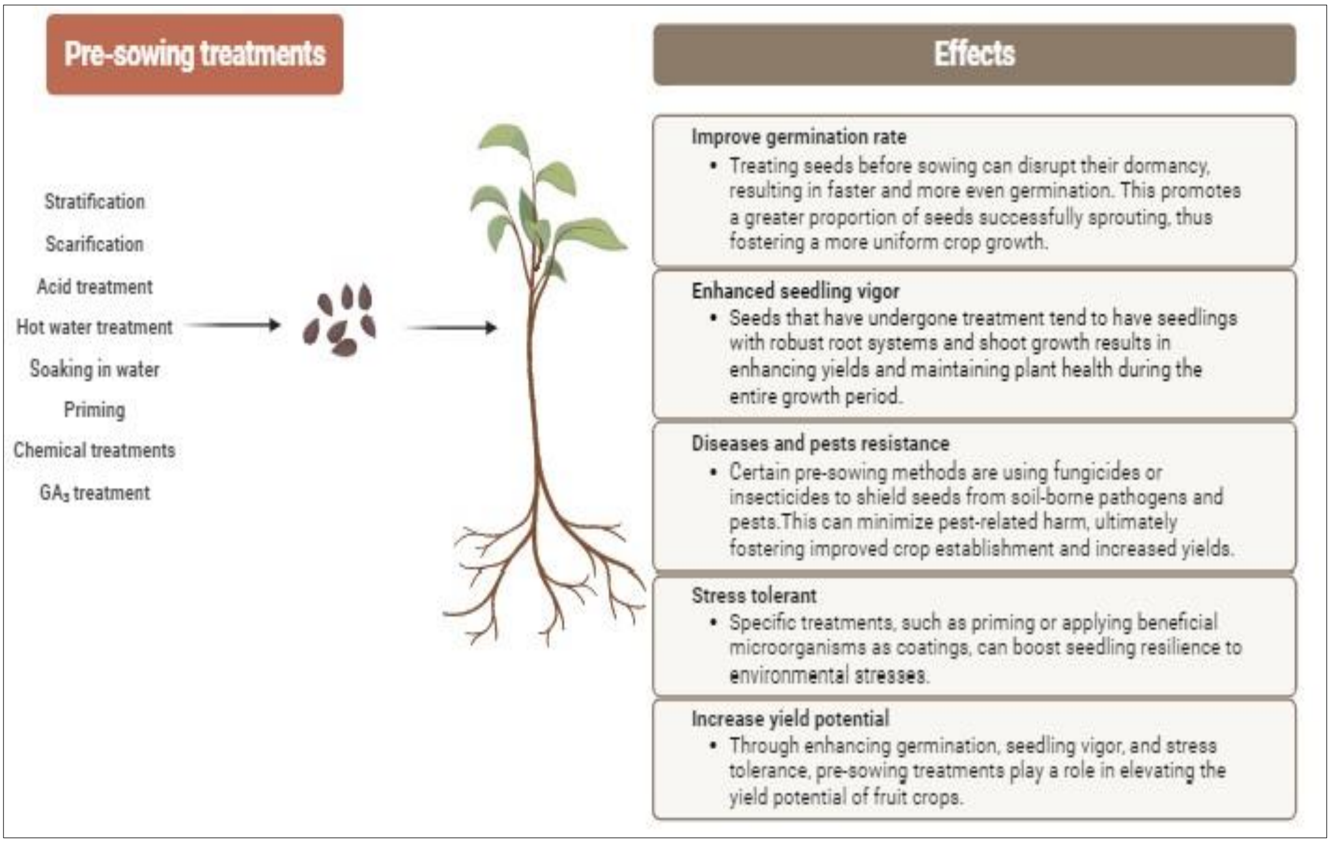

Fig 1: Effect of pre-sowing treatments on seed germination and growth

Effect of pre-sowing treatments on germination percentage and seedling growth of different fruit crops

Treating mango seeds with KNO_3 (0.5%) was identified as an effective practice as it resulted in notably superior outcomes across various growth parameters. This treatment exhibited higher values for key attributes such as germination percentage (64%), seedling vigor (1094.33), seedling diameter (7.10 mm), leaf count (10.90), leaf dimensions (15.83 cm x 8.00 cm), root length (23.40 cm), root spread (8.66 cm), vigor index (1517.30) and root to shoot ratio (0.807) in comparison to alternative methods. In contrast, the highest seedling height (24.13 cm) and internodal length (3.66 cm) were found in the extracted kernel that had been pre-treated with 500 ppm of GA_3 (Aatla and Srihari, 2013). Reshma and Simi (2019) conducted research on pre-sowing treatments for mango seeds, which involved immersing the seeds in different solutions including KNO_3 (1 and 2 ppm), cow dung slurry, GA_3 100 ppm, GA_3 200 ppm and a control for 24 hours. The vigor indices I and II showed a consistent inverse correlation with the germination time. There was a strong correlation between germination percentage and rate with vigor index-I (R2 = 0.95 & 0.89) and vigor index-II (R2 = 0.89 & 0.95) respectively. The treatments applied before sowing directly impacted the growth and germination of mango seedlings, resulting in enhanced vigor. While, the mango seeds were subjected to different pre-sowing treatments including KH_2PO_4 at 1%, KNO3 at 1%, KCl at 1%, and sucrose at 1%. The findings indicated that soaking the seeds in a 1% sucrose solution enhanced both the germination percentage and subsequent growth of mango seedlings (Sangeetha and Mani, 2015) [24]. Pre-sowing treatments for guava seeds included scraping the seed coat with sandpaper, GA_3 at 100 ppm for 24 hours, GA_3 at 200 ppm for 24 hours, a combination of scraping the seed coat with sandpaper and soaking seeds in GA_3 at 100 ppm for 24 hours, a combination of scraping the seed coat with sandpaper and soaking seeds in GA_3 at 200 ppm for 24 hours, soaking in 0.1% and 0.2% potassium hydroxide solutions for 2 minutes each, soaking in 30% sulfuric acid for varying time intervals (1 minute and 3 minutes), soaking in 5% and 10% HCl for 2 minutes each, soaking in hot water at 80 °C (3 min and 1 min), and immersed in water for 48 hours. The study results demonstrated that these pre-sowing treatments significantly affected the development of guava seedlings. Among them, the most effective treatment was scraping the outer layer of seed with sandpaper and GA_3 at 200 ppm for 24 hours. This treatment yielded the highest values for seedling height (4.59 cm), shoot length (6.75 cm), number of leaves per seedling (12.40), root length (5.85 cm), seedling leaf area (3.83 cm2), and total chlorophyll content (29.85 SPAD units) (Kumar *et al*., 2022). Similarly in previous studies GA_3 at 150 mg/L proved to be the most effective in enhancing germination percentage (80.77%), reducing germination time (16.73 days) as well as in growth parameters such as leaf count (7.80, 14.33, 17.93), stem diameter (0.87, 2.22, 2.75 mm), seedling height (7.28, 15.07, 28.18 cm), primary root length (6.72 cm), secondary root count (26.40), shoot fresh weight (14.21 g), shoot dry weight (5.97 g), root fresh weight (1.94 g), shoot-to-root ratio (7.32), root dry weight (1.12 g) and (75.00%) survival percentage (Boricha *et al*., 2020) [3].

Jaiswal (2016) [12] examined the impact of various pre-sowing treatments on the germination and growth of Kagzi lime. The study revealed significant differences in germination rates and seedling development due to these treatments. Soaking the seeds in GA_3 solution of 80 ppm before sowing resulted in the highest germination percentage (95.00%). Additionally, this treatment led to the tallest seedlings (30.02 cm), the highest leaf count (28.62), and the greatest dry weight of shoots (10.04 g) fresh weight (20.60 g) at 180 days after sowing (DAS). Similarly, Chaudhary *et al*., (2020) [6] explored various pre-sowing treatments for Kagzi lime seeds, focusing on soaking durations of 24 hours and 12 hours in aqueous solutions of gibberellic acid (GA_3) at 200 ppm to 500 ppm. The findings revealed that the 12-hour soaking duration consistently outperformed the 24-hour duration across all treatments. Specifically, the application of GA_3 at 500 ppm resulted in the highest values for total chlorophyll content, leaf area, and tap root diameter, demonstrating significant superiority. Moreover, the treatment with 400 ppm GA_3 exhibited the highest values for shoot dry weight, tap root length and total dry weight, which were also statistically significant. Pummelo seeds underwent various treatments, including immersed in water for 24 hours, scalding at 50 °C for 24 hours, and soaking in GA_3 solutions of different concentrations for 24 hours. Upon analysing the results, it was concluded that the combination treatment of soaking freshly harvested seeds in GA_3 at 50 ppm for 24 hours followed by scalding at 50 °C for 24 hours yielded the most favorable outcomes in terms of germination percentage and various growth parameters of pummelo seedlings compared to the control (Khopkar *et al*., 2017) [14].

Singh and Maheswari (2017) [28] studied about the influence of pre-sowing seed treatments on *Annona muricata* L. seedlings. The treatments included scarification all around the seed, scarification at the hilum point, soaking in water for 24, 48, and 72 hours, concentration of H_2SO_4 for 5, 10, and 15 minutes, GA_3 500 ppm, GA_3 250 ppm and control. The results of the research proved that out of all the treatments tested, GA_3 at 500 ppm produced the highest values for the seedlings shoot length, germination percentage, root length, stem girth, number of leaves and vigour index.

The *Prunus mahaleb* L. seed, which is utilised as a rootstock for cherry cultivation, has a poor germination and emergent rate because to its dormant state. A combination of hot water treatment at different durations followed by stratification, sulfuric acid scarification at different duration and GA_3 for 0, 500, 1000, and 2000 ppm has been used as treatments. The result showed that stratification for 60 days increase the germination percentage and lowered the mean germination time. The germination rate and speed were only enhanced by scarification with sulfuric acid or hot water followed by a 60-day stratification period. The germination rate of the seedlings increased dramatically when they were treated with GA_3. Treating stratified seedlings with GA_3 at 1000 ppm resulted in the best germination rates during 60 and 90 day periods. It is recommended to incorporate GA_3 alongside cold stratification to increase the rate and percentage of mahaleb cherry seed germination (Al-Absi 2010) [2].

Papaya seeds treated with 0.5% KH_2PO_4 solution exhibited the shortest durations for both germination initiation (8.67 days) and reaching 50% germination. These treated seeds also demonstrated the highest germination rate, germination index, tap root length (26.33 cm), shoot dry weight (2.00 g), number of lateral roots per seedling (22.84), root dry weight (0.79 g), seedling quality index (0.47), and 100% seedling survivability. Furthermore, this treatment showed increased chlorophyll content (3.51 and 3.91 mg/g), photosynthetic rate (15.32 and 17.76 µmol CO_2 m^{-2} s^{-1}), transpiration rate (4.61 and 5.69 mmol m^{-2} s^{-1}), and stomatal conductance (2.73 and 4.12 mol m^{-2} s^{-1}) at 35 and 45 days after sowing (DAS) respectively. Conversely, the treatment with 2 mM salicylic acid exhibited the lowest values for both germination and growth parameters. Among all treatments, the application of 0.5% KH_2PO_4 proved to be the most effective, followed by 0.5% KNO_3 enhancing germination, growth, and physiological traits (Rao *et al*., 2023) [22].

Papaya seeds were planted in polybags containing standard soil mixture and subjected to various treatments, including three different concentrations of GA_3 (50, 100, and 150 ppm) along with 10% cow urine and the addition of bio-fertilizers to the soil. The findings indicated that the treatment involving seed soaking in 150 ppm GA_3 for 12 hours along with azotobacter resulted in early germination, faster emergence rates, and the highest percentage of germination, as well as superior seed vigor indices (Lanjhiyana *et al*., 2020) [16].

Table 1: Pre-sowing treatments of different fruit crops

Fruit Crop	Pre-sowing treatment	Result	Reference
Apple	Stratification at 3 °C for 90 days in solution of salicylic acid (SA), jasmonic acid (JA) at 10^{-3} M, GA_3, and 6-benzylaminopurine at concentrations of 250 mg·dm^{-3} and 100 mg·dm^{-3}.	Best in GA_3 alone or in combination with JA, BAP, GA_3 and SA. This suggests that stratification is an efficient approach to enhance and expedite germination of seed and the growth of seedlings, ultimately reducing the duration of the apple breeding cycle.	Górnik *et al*., 2018 [10]
Banana	Exposing the endosperm, mechanically scarification, immersing in gibberellic acid, excising zygotic embryos, and chemically scarification using sulfuric acid (H_2SO_4) with different immersion durations	Germination was successful only through excised zygotic embryos and chemical scarification. With excised zygotic embryos, germination reached or exceeded 90% within a period of 21 days.	Burgos-Hernández *et al*., 2014 [4]
Aonla	The aonla seeds were subjected to pre-soaking treatments involving GA_3, cow urine, thiourea, water, seed stratification and sulfuric acid for durations of 12 and 24 hours.	GA_3 at 500 ppm for 24 hours resulted in early germination and increased seed germination rates.	Singh and Kaur 2021 [26]
Mango	Seeds without seed coats were immersed in cool water (5 °C) for 12 hours, heated water (15 °C) for 1 minute, and seeds having seed coats planted as a control.	Seeds without seed coats were immersed in warm water of 15 °C for one minute had the best result having 80% of germination	Jakpa *et al*., 2019 [13]
Watermelon	Seeds were subjected to priming using various media, including 0.1N HCl, 1.5N NaCl, 3% PEG 6000, 3% KNO3, and a control group without any priming.	Among the different priming media tested, KNO_3 exhibited the most beneficial effects on emergence and seedling growth. KNO_3 treatment showed increases in germination, germination rate, and plumule length by 17.87%, 18.65%, and 4.68%, respectively.	Armin *et al*., 2010 [32]
Papaya	Papaya seeds were immersed in solutions containing $Ca(NO_3)_2$ and KNO_3 at concentrations of 10000 ppm, 15000 ppm, and 20000 ppm for a duration of up to 24 hours.	The shortest duration for seed germination (4.33 days), the highest percentage of germination (82.56%) and the longest shoot length (14.31 cm) were observed in the treatment with 10000 ppm $Ca(NO_3)_2$.	Maneesha 2019 [17]

Conclusion

Pre-sowing treatment of seeds in fruit crops is essential for maintaining good the germination process seedling establishment, and production of crops. Pre-sowing treatments can eradicate infections, interrupt seed dormancy, and increase seedling vigour by treating seeds with disinfection, scarification, or priming techniques. These treatments not only enhance uniform germination, but also provide developing seedlings with the resilience needed to endure environmental challenges and compete effectively against weeds. Also, pre-sowing treatments boost nutrient absorption and disease resistance, resulting in larger yields and better fruit quality. In basically, pre-sowing seed treatment is an important part of fruit crop management techniques since it improves seedling performance and ensures long-term results.

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