



RESEARCH ARTICLE

Effect of organic seed treatments and soaking duration on seedling growth and survival of papaya (*Carica papaya* L.)

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Abstract

Papaya seed germination is often slow and erratic due to mechanical restrictions from the seed coat (gelatinous sarcotesta) and imposed physiological dormancy. Seed priming effectively releases dormancy from seeds by exposing them to specific substances for specific times that trigger metabolic activities associated with germination. Although, organic substances such as Beejamrit and Jeevamrit are now being used in several crops for seed priming. However, their comparative effects on papaya seed germination are not well understood. The purpose of this experiment was to evaluate various organic substances to improve papaya seed germination and seedling growth. The experiment was carried out at Krishi Vigyan Kendra, Sardarkrushinagar Dantiwada Agricultural University (SDAU), Tharad, Gujarat, using plastic pro trays under 50 % green shade net in complete randomized design comprised with two factors (S); organic substance viz., S₀ (water soaking), S₁ (Beejamrit), S₂ (Jeevamrit 10 %), S₃ (cow dung extract), S₄ (novel organic liquid nutrient 1.0 %) and S₅ (15 days old fermented buttermilk) and different seed soaking duration viz., D₁ (6 hr), D₂ (9 hr) and D₃ (12 hr). The results revealed that treatment S₁ (Beejamrit) demonstrated the fastest germination (18.28 days), highest germination per cent (71.21), lesser days to 7–8 leaf stage (59.94), higher seedlings height (10.80 cm), longest primary roots (9.58 cm), highest survival of seedling (92.58 %) and survival per cent of papaya seedling (94.54) after 5 days of planting in the field. In case of soaking durations, treatment D₃ (12 hr soaking) recorded the earliest germination (17.87 days), exhibited higher germination per cent (69.50), took shortest time (58.77 days) to attained 7–8 leaf stage, maximum seedling height (10.23 cm) and the longest primary roots (8.40 cm). However, the seed soaking duration was found statistically non-significant on survival per cent of the seedlings at planting and after transplanting in the field.

Keywords: Beejamrit; germination; Jeevamrit; microbial activity; organic substances

Introduction

Papaya is botanically known as (*Carica papaya* Linn.) and belongs to the family Caricaceae (1). It is the fastest growing tropical or subtropical fruit plant (2). The plant characterised by a hollow, soft trunk, large and palmate leaves (3) with orange red sweet flesh and numerous black seed (4). Papaya fruits are nutritionally enriched with high vitamin A, vitamin C, vitamin E, folate, potassium, calcium, magnesium and fibres. The fruits are rich in antioxidants like carotenoids, especially lycopene and beta-carotene, help in digestion and heart health and has anticancer properties (5). It is an important fruit crop cultivating in Gujarat state as well as in the other tropical and sub-tropical regions of India. India leads the world in both area and production of papaya for over 43 % of global output (6) with 1.53 lakh ha area and 57.57 lakh MT production (7). In terms of production share of the states, Andhra Pradesh is the leading, while Gujarat ranks second with a contribution of about 17.5 % (7). In Gujarat, papaya cultivated on 0.18 lakh ha, producing 10.61 lakh MT with a productivity of 58.07 MT/ha (8). Tapi, Kutch, Anand, Baroda, Bhavnagar, Kheda, Junagadh and Mahesana are the major papaya producing districts (9).

Commercially papaya are raised by the seeds. However, papaya seed germination faces several barriers, such as hard seed coats with gelatinous sarcotesta (10), presence of inhibitory substances (11) and susceptibility to fungal infections (9) resulting in inconsistent and slow sprouting. Since papaya seed exhibit physiological dormancy (12, 13) and the low permeability of the seed coat further restricts water uptake, they exhibit a reduced germination percentage and a prolonged germination period. Consequently, germination is often poor and non-uniform, which makes the production of many healthy seedlings a major challenge for papaya growers (14, 15). Although several studies have reported the use of pre-sowing treatment of papaya seeds with plant growth regulators such as gibberellic acid (GA₃), naphthalene acetic acid (NAA) and benzyl adenine (BA) enhance seed germination (16–20). That overcome dormancy and significantly improve papaya germination and seedling vigour. The demand for organically grown seedlings has increased significantly in recent years due to growing consumer awareness of health, sustainability and food safety.

Organic substances such as Jeevamrit, Beejamrit and buttermilk are gaining attention as substitutes for this (21, 22). Beejamrit and Jeevamrit are cow based bioformulations particularly used in natural farming systems such as zero budget natural farming (23). Beejamrit prepared from cow dung, cow urine, lime and soil, primarily applied as a seed treatment (24). As per traditional literature, Beejamrit is regarded as a magical liquid for seed due to its effectiveness in protecting seeds from pathogens and enhancing germination and early plant growth (25). In contrast, Jeevamrit is a fermented liquid organic formulation made from cow dung, cow urine, jaggery, pulse flour and soil (26), serves as a microbial inoculant and nutrient source for soil (27). These preparations are rich in beneficial microbes, enzymes and natural growth-promoting substances (28, 29), which help in soften the seed coat, enhance microbial activity in the rhizosphere and improve nutrient availability.

Their use not only promotes quicker and more uniform germination but also supports healthier seedling development, thereby providing a sustainable and eco-friendly approach to papaya crop establishment (30). Seed priming using organic substances with different soaking durations could enhance germination per cent and growth of papaya seedling. The present investigation was planned to find out the Influence of different organic substances and seed soaking duration on germination, growth and survivability of papaya seedling.

Materials and Methods

The experiment was conducted during January to March 2024 and 2025 at Krishi Vigyan Kendra SDAU, Tharad, Gujarat, in papaya cultivar GJP-1 (Gujarat Junagadh Papaya-1). The experiment was conducted in plug trays under 50 % green shade net. Cocopeat + vermicompost (1 : 1 v/v) was used as rooting medium. The experiment was comprised of two factors, (S) organic substance viz, S₀ (water soaking), S₁ (Beejamrit), S₂ (Jeevamrit 10 %), S₃ (cow dung extract), S₄ (novel organic liquid nutrient 1.0 %) and S₅ (15 days old fermented buttermilk) and factor (D) different time duration of seed soaking D₁ (6 hr), D₂ (9 hr) and D₃ (12 hr). The cow dung was prepared (with mixing cow dung in clean water at 1:10 ratio (1 kg cow dung + 10 L of water) stir to form a uniform slurry, kept it in shaded area for 24 hr for fermentation then filtered the liquid using a muslin cloth then the liquid extract 10 % solution was used. Fifteen days old, fermented buttermilk at 1 : 1 diluted solution was used. Beejamrit and Jeevamrit were prepared as per the standard procedure given in the generic protocol for natural farming of Indian Council of Agricultural Research (ICAR) (31). The Beejamrit consisting of fresh cow dung (5 kg), cow urine (5 L), lime (50 g) and a handful of rhizospheric soil mixed in 20 L of water. The mixture was stirred thoroughly and incubated under shade for 24 hr before use. However, the Jeevamrit was prepared as per recommended procedures using cow dung (10 kg), cow urine (10 L), jaggery (2 kg), pulse flour (2 kg) and a small quantity of soil in 200 L of water and allowed to ferment for 5–7 days with regular stirring and a 10 % solution was used for seed soaking. A ready-made formulation of a novel organic liquid nutrient was used in the present study; it is a banana pseudo-stem based organic liquid nutrient. The nutritional and biochemical composition of the product was adopted from (32). Quantity of solution for soaking was used at 1000 mL/kg seeds for all the treatments. The experiment was laid out in a completely randomised design with factorial concept with 3 replications. Days

to germination was recorded based on the emergence of at least three seeds and recorded upon the emergence of at least three seeds, while days to 7–8 leaf stage were noted when three seedlings reached this stage. Survival percentage, plant height and root length were measured when seedlings reached the 7–8 leaves stage. The field survival per cent was recorded after 5 days of transplanting (DAT).

Results

Days to germination

The data illustrated in Table 1 indicated that the treatment, S₁ (Beejamrit) demonstrated the fastest germination (18.28 days) in case of soaking durations, D₃ (12 hr soaking) germinated the fastest (17.87 days). While shorter soaking durations of 6 hr resulted in delayed germination (21.74 days). The papaya seeds soaked in Beejamrit for 12 hr enhanced early germination, compared to other treatment tested including control.

Germination per cent

The data shown in Table 1 indicated that S₁ (Beejamrit) showed the significantly highest germination (71.21 %), followed by the treatment S₄ (novel organic liquid nutrients 1.0 %) with (65.52 %). In contrast, control recorded the lowest germination per cent. In case of seed soaking durations, the best results were observed with treatment (D₃) 12 hr soaking (69.50 %). Beejamrit combined with a 12 hr soaking period resulted in the highest germination per cent.

Days taken to 7–8 leave stage of papaya seedling

Data reflects in Table 1 indicated that the S₂ (Beejamrit) took significantly lesser days to 7–8 leaves stage (59.94 days), followed by S₄ (novel organic liquid nutrients 1.0 %) 62.52 days. In case of seed soaking durations, the shortest time to 7–8 leaves development was observed with a D₃ (12 hr soaking) period with (58.77 days). Beejamrit with 12 hr of soaking resulted in the fastest development of 7–8 leaves.

Height of the seedling (cm)

The data showed in Table 1 indicated that the S₂ (Beejamrit) resulted significantly higher seedlings height (10.80 cm), followed by the treatment S₄ (novel organic liquid nutrients 1.0 %) 10.03 cm. In case of soaking durations, the tallest seedling (10.23 cm) was observed with D₃ (12 hr soaking). In case of interaction, treatment S₁D₃ was produced statistically maximum seedling height (11.63 cm), however treatment S₄D₃ (11.46 cm) was found at par with it.

Root length of seedling (cm)

The data showed in Table 1 indicated that the S₁ (Beejamrit) resulted significantly longest primary roots (9.58 cm), followed by S₄ (novel organic liquid nutrients 1.0 %) 8.77 cm. In case of seed soaking durations, the longest primary roots were recorded in D₃ (12 hr soaking), with (8.40 cm). The interaction between treatments and soaking durations was found significant (Beejamrit) with D₃ (12 hr soaking) resulted in the maximum primary root length.

Survival per cent at planting

The results showed in Fig. 1 indicated that S₁ (Beejamrit) exhibited highest survival of seedling (92.58 %), followed by the treatment S₄ (novel organic liquid nutrients 1.0 %) 91.93 %. In case of duration of seed soaking had a non-significant effect on survival at transplanting.

Table 1. Effect of different organic substances and time of seed soaking on days to germination, germination per cent, days to attained 7-8 leaves, seedling height and root length of papaya seedling cv. GJP-1

Treatments	Days to germination	Germination (%)	Days taken to 7-8 leaves	Seedling height (cm) at 7-8 leave stage	Root length (cm) at 7-8 leave stage
Substances (S)					
S ₀ : Control (water soaking)	20.76	52.06	63.12	8.37	6.68
S ₁ :Beejamrit	18.28	71.21	59.94	10.80	9.58
S ₂ : Jeevamrit (10 %)	19.78	59.40	64.46	9.84	8.31
S ₃ : Cow dung extracts (10 %)	19.83	60.08	64.55	10.03	8.40
S ₄ : Novel organic liquid Nutrient (1.0 %)	18.72	65.52	62.52	10.30	8.77
S ₅ : Fermented buttermilk (15 days old)	22.55	55.42	66.21	8.71	6.88
S.E.m.±	0.67	1.33	0.38	0.24	0.14
C D ($p = 0.05$)	2.46	4.84	1.09	0.89	0.39
Seed soaking time (D)					
D ₁ : 6 hr	21.74	53.54	67.44	9.24	7.72
D ₂ : 9 hr	20.35	58.81	64.16	9.55	8.19
D ₃ : 12 hr	17.87	69.50	58.77	10.23	8.40
S.E.m. ±	0.17	1.26	0.27	0.93	0.09
C D ($p = 0.05$)	0.50	7.70	0.77	0.26	0.27
Interaction					
S ₀ D ₁	21.33	50.48	71.50	8.14	6.77
S ₀ D ₂	21.30	51.00	59.33	8.52	6.72
S ₀ D ₃	19.66	54.71	58.49	8.45	6.54
S ₁ D ₁	22.80	67.36	63.17	10.31	9.15
S ₁ D ₂	17.50	66.81	64.00	10.46	9.68
S ₁ D ₃	14.54	79.45	52.67	11.63	9.92
S ₂ D ₁	20.66	49.00	67.34	9.28	6.91
S ₂ D ₂	20.16	58.64	67.00	9.95	8.74
S ₂ D ₃	18.51	70.58	59.05	10.30	9.29
S ₃ D ₁	21.33	48.23	67.49	9.30	7.75
S ₃ D ₂	19.50	59.40	66.34	9.91	8.32
S ₃ D ₃	18.66	72.63	59.83	10.88	9.14
S ₄ D ₁	21.66	54.86	67.84	9.50	8.87
S ₄ D ₂	21.50	63.85	64.33	9.95	8.62
S ₄ D ₃	13.17	77.86	55.39	11.46	8.82
S ₅ D ₁	22.66	51.31	67.34	8.95	6.86
S ₅ D ₂	22.16	53.20	64.00	8.51	7.08
S ₅ D ₃	22.83	61.76	67.28	8.68	6.71
Interaction effect					
S × D					
S.E.m. ±	0.43	1.28	0.67	0.22	0.24
C D ($p = 0.05$)	1.23	3.61	1.89	0.64	0.68
CV (%)	5.38	5.18	2.59	5.75	7.33

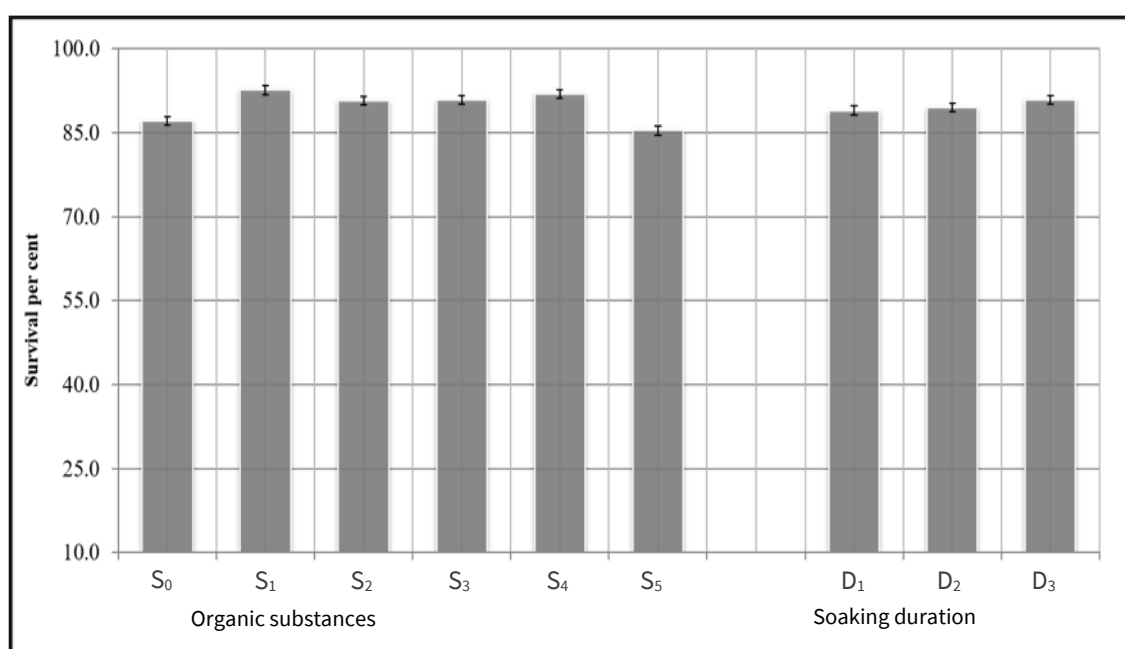


Fig. 1. Effect of different organic substances and seed soaking duration on survival per cent at transplanting of papaya.

Survival per cent after 5 days of transplanting

The results presented in Fig. 2 revealed that the Beejamrit showed highest survival of papaya seedling (94.54 %) after 5 days of planting, followed by the treatment S₄ (novel organic liquid nutrients 1.0 %), 93.15 %. In case of duration, seed soaking had a non-significant effect on survival after five days of transplanting.

Economics

The data showed in Table 2 indicated that among all treatments, S₁D₃ (seed soaked in beejamrit for 12 hr) achieved the highest performance with a gross realisation of ₹1873 per m², a net realisation of ₹1360 per m² and the highest benefit-cost ratio of 2.7 for papaya seedling production.

Discussion

Days to germination

The seeds treated with Beejamrit (S₁) and soaked for 12 hr (D₃) recorded the earliest germination, while shorter soaking duration (6 hr) delayed germination. This indicates that both the type of treatment and duration of soaking play an important role in

Table 2. Economics of various treatments per square metre area

Treatments	Total cost (₹/m ²)	Gross realisation (₹/m ²)	Net realisation (₹/m ²)	B:C ratio
S ₀ D ₁	511.91	1102	590	1.2
S ₀ D ₂	511.91	1131	619	1.2
S ₀ D ₃	511.91	1196	684	1.3
S ₁ D ₁	512.71	1565	1052	2.1
S ₁ D ₂	512.71	1549	1037	2.0
S ₁ D ₃	512.71	1873	1360	2.7
S ₂ D ₁	512.21	1094	582	1.1
S ₂ D ₂	512.21	1342	830	1.6
S ₂ D ₃	512.21	1612	1100	2.1
S ₃ D ₁	511.93	1078	566	1.1
S ₃ D ₂	511.93	1362	851	1.7
S ₃ D ₃	511.93	1701	1189	2.3
S ₄ D ₁	512.11	1249	737	1.4
S ₄ D ₂	512.11	1477	965	1.9
S ₄ D ₃	512.11	1836	1324	2.6
S ₅ D ₁	511.91	1128	616	1.2
S ₅ D ₂	511.91	1118	607	1.2
S ₅ D ₃	511.91	1330	818	1.6

initiating early germination. The early germination in Beejamrit treated seeds may be attributed to its rich microbial population and nutrient content. The beneficial microorganisms such as nitrogen fixers and phosphorus solubilisers create a favourable environment around the seed (33). The Beejamrit is traditionally prepared using cow dung, cow urine, lime and soil (28) which are reported to harbour diverse microbial populations and bioactive compounds such as natural enzymes, plant growth hormones and antimicrobial agents (23, 25, 34). The presence of a gelatinous sarcotesta in papaya seed acts as a significant physical and chemical barrier that restricts water penetration and gas exchange. Due to this barrier papaya seeds generally require more time for proper imbibition (35). The adequate soaking duration is important for better absorption of the treatment solution by the seeds. This improves the availability of nutrients and microbial activity on the seed surface and activate the germination processes. Soaking of papaya seeds for 8–12 hr is considered optimal for enhancing germination rates. Previous results reported better germination in papaya seed after soaking for 12 hr (36–38). The early germination of papaya seeds in 14.28 days when seeds soaked for 24 hr in water and removed sarcotesta (39). In contrast, shorter soaking duration (6 hr) may not provide sufficient exposure for these beneficial effects, resulting in delayed germination.

Germination per cent

Beejamrit combined with a 12 hr soaking period resulted in the highest germination per cent. Beejamrit, as an organic preparation, not only helps boost germination but also assists in protecting young roots from fungal infections, thereby potentially improving overall seedling establishment rates. A higher germination percentage (62.84) in jackfruit when seeds were soaked for 12 hr in cow dung slurry (40). However, the seed treatment with Beejamrit at 75 % concentration resulted in the highest germination percentage in chickpea (41). Further, high germination percent in rice seeds with Beejamrit was reported (42). The cow's urine has antifungal and antibacterial properties that disinfect the seed surface (43), while lime in Beejamrit maintains suitable pH conditions around the seed for improved germination (44). Moreover, the microbial activity and bioactive compound of Beejamrit improve the seed microenvironment and facilitate water imbibition, leading to

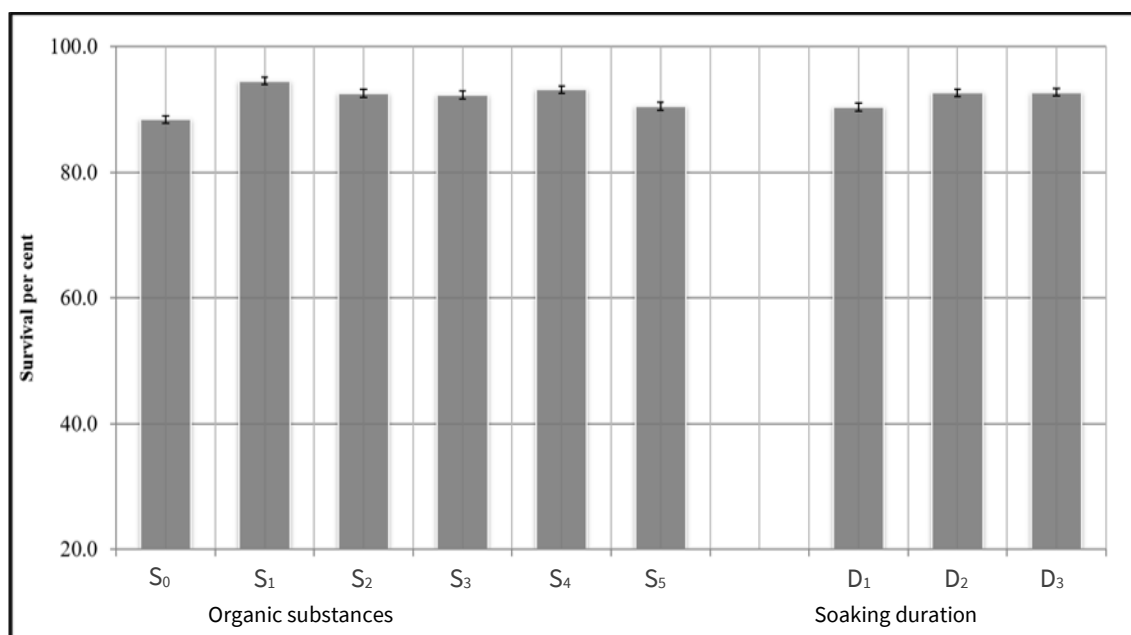


Fig. 2. Effect of different organic substances and seed soaking duration on survival per cent after transplanting of papaya.

enhanced metabolic activation and increased activity of hydrolytic enzymes such as amylase and protease (25, 45). Additionally, the presence of diverse beneficial microorganisms and metabolites in Beejamrit may act synergistically to promote seed germination and support healthy plant growth (34, 41).

Days taken to 7–8 leave stage of papaya seedling

The Beejamrit contain plant-beneficial bacteria, these microbes are responsible for synthesizing plant growth-promoting substances (25, 28). The fermentation and microbial action produce bioactive compounds, including enzymes (46) help in breakdown of nutrients and plant hormones such as indole 3 acetic acid (IAA) and gibberellic acid (GA₃) that stimulate early growth (28).

Height of the seedling (cm)

The enhanced seedling growth observed under Beejamrit treatment may be attributed to the presence of diverse microorganisms and bioactive compounds that stimulate cell division and overall plant development (25). Additionally, cow's urine, a key constituent of Beejamrit, contains plant growth-promoting substances such as auxins and cytokinins (25, 28, 47) which enhance root development and nutrient uptake, thereby supporting seedling growth (48). Supporting these findings, early researches reported the highest shoot length (18.13 cm) in chickpea seed treated with Beejamrit 75 % concentration (41). Similarly, maximum seedling length observed and seed vigour index (SVI) in groundnut and green gram under 100 % Beejamrita treatment (45). The pre-soaking mango stones with 100 % Beejamrit significantly improved germination and vigour index with the highest seedling length (26.39 cm) (49). In addition, significant increases in seedling growth parameters, including plant height under Beejamrit seed treatment in rajma was documented (50). The seed soaking with 3 % Beejamrit resulted in the highest increase in seedling height in khirni (51). The seeds treated with Beejamrit showed maximum seedling length (36.90 cm) at 180 days after sowing in Kaagzi lime (52). In contrast, higher seedling length and vigour in green gram seed recorded with 100 % cow dung extract (24). Collectively, these findings indicate that Beejamrit enhances early plant growth through the synergistic effects of microbial activity, bioactive metabolites and plant growth-promoting substances.

Root length of seedling (cm)

Beejamrit was found to be an effective seed treatment for promoting primary root growth when papaya seeds were soaked for 12 hr. This improvement may be due to better microbial activity, improved nutrient availability and proper activation of seeds during germination. The results are in line with earlier studies reported on seed priming, Beejamrit was superior to control for better root length of chilli (53). Similarly, higher radicle and coleoptile length in rice seedlings from Beejamrit treated seeds (42). Beejamrit (100 %) treatment gave the highest seedling length in rajma, along with better seed vigour and healthier seedlings compared to untreated seeds (50). However, the maximum root length in chickpea was observed when seeds were treated with Beejamrit (75 %) (41).

Survival per cent at planting

The enhanced survival may be attributed to the high microbial density and diverse bioactive constituents present in Beejamrit (25, 28, 54) and the banana pseudo-stem sap based novel organic liquid formulation (55). These formulations facilitate the colonisation of the seed surface by beneficial microorganisms which

stimulate early enzymatic activity, accelerate germination and promote rapid root initiation (56). Additionally, microbial antagonism contributes to the suppression of seed and soil-borne pathogens, thereby reducing early-stage mortality (57). As per the study reported Beejamrit treated seeds exhibited higher germination per cent and seedling vigour in soyabean seed which was attributed to increased microbial activity and nutrient mobilization (28). Similarly, Beejamrit and Jeevamrit significantly enhance rhizosphere microbial populations and nutrient availability, thereby promoting early plant growth and survival (58). Further confirmed that khirni seeds soaked in 3 % of Beejamrit for 72 hr gave higher seedling survival (51).

Survival per cent after five days of transplanting

Higher survival of transplanted seedlings with Beejamrit treatment might be due to the activity of beneficial microbes such as nitrogen fixers, phosphate and potassium solubilisers and IAA producers (25, 41) which enhance nutrient availability and root growth (59). These microbes also suppress soil-borne pathogens and create a healthy rhizosphere (34), resulting in better root establishment, reduced transplant shock and improved seedling survival. These results are supported by early findings of cow pea (24) and khirni (51).

Economics

Beejamrit is a cost effective and eco-friendly seed treatment substances prepared from the materials which are easily available on the farm that promote seed germination and seedling growth. Beejamrit at 75 % concentration has been reported as a low-cost and effective seed treatment for chickpea (41). Since it is prepared from cow-based inputs that reduces the input expenses (33). Its rich microbial composition improves seed germination, protects against soil-borne pathogens, enhances seedling growth and contributing to higher economic returns (60). Therefore, the higher benefit-cost ratio obtained from the treatment S₁D₃ (soaking of papaya seed in Beejamrit 100 % solution for 12 hr) might be due to the combined effects of lower input costs and better biological efficiency, which makes Beejamrit a profitable and sustainable option for papaya seedling production.

Conclusion

The findings demonstrated that the papaya seeds soaked with Beejamrit resulted in the fastest germination, highest germination per cent, lesser days to 7–8 leaves stage, higher seedlings height, longest primary roots, highest survival of seedling and survival per cent of papaya seedling after 5 days of planting in the field. Further, the treatment S₁D₃ (seed soaked in Beejamrit for 12 hr) was found better for maximum net realisation and benefit-cost ratio. Based on these findings, papaya seedling producers are suggested to soak papaya seeds in Beejamrit solution for 12 hr and raise seedlings in plug trays filled with cocopeat and vermicompost (1 : 1) under a 50 % green shade net to ensure uniform, healthy and economically viable seedling production.

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Authors' contributions

PS performed the data analysis and drafted the manuscript. YDP, PV provided proper guidance in experiment designing. MPC collected the data. BMN involved in drafting, reference collection, editing and revision of the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used ChatGPT to improve the language. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication

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