COLLEGE OF AGRICULTURE AND NATURAL RESOURCES

DEPARTMENT OF HORTICULTURE

EFFECT OF SEED PRIMING AND GROWING MEDIA ON PAPAYA (C*arica papaya* L.) SEED GERMINATION

SENIOR RESEARCH PROJECT PROPOSAL (HORT491)

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WOLKITE UNIVERSITY, ETHIOPIA

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A Senior Research Project Proposal

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LIST OF ABBREVIATIONS

CSA Central statistics agency

FYM Farmyard manure

GA3 Gibberellic acid

KNO_3 Potassium nitrate

LIST OF TABLE

TABLE OF CONTENTS PAGE

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ABSTRACT

Papaya (Carica papaya L.) is a short-lived perennial plant in the genus Carica under the family of Caricaceae. Papaya is an important tropical and subtropical fruit with many nutritional, medicinal and economic values. It is a highly significant fruit crop in Ethiopia, with a dual function of being exported and consumed locally both raw and processed. Production has not kept up with demand. Papaya is mainly propagated by seeds which show wide variability in germination and seedling growth. Seed priming before sowing is well documented to enhancing seed germination and breaking dormancy. Growing media is give necessary ingredients and physical support to the seedling. This study aimed to investigate the impact of seed priming specifically using potassium nitrate and gibberllic acid in combination with different growing media compositions on germination of papaya seed from February to May 2024 at Wolkite University in horticulture libratory. A Complete Randomized Design (CRD) with nine treatments and three replications was employed to evaluate seed germination rate, seedling vigor, and other germination and growth parameters. The analysis of variance indicated that treatments had very differently responded ($P<0.01$) on papaya seed germination and almost measured parameter trait as analyzed in SAS. The result indicated that seed priming with potassium nitrate and growing Medias of farm yard manure, red soil and sand significantly influenced seed germination and early growth parameter.

Key word seed priming; germination percentage; growing media; papaya (Carica papaya L.).

1. INTRODUCTION

Papaya (*Carica papaya* L.) is a short-lived perennial plant in the genus Carica under the family of Caricaceae. Papaya is an important tropical fruit with many nutritional, medicinal and economic values (Ayele et al., 20217) mainly in the tropical and warmest parts of subtropical regions of the world (Fikre and Mensa, 2021).The fruit is a stack house of innumerable nutrients. The fruit is also called as the fruit of wonders in the tropical regions (Rana*et al*. 2020). It is highly rich in vitamin A and contains significant amount of vitamin B2 and many other nutrients (Rana*et al*., 2020). Papaya fruits are one of the most valuable fruit harvests and are highly regarded for their great nutritional value, therapeutic properties, and variety of other uses, such as cosmetic, food canning industries, and more (Serrano and Cattaneo, 2010). It is a highly significant fruit crop in Ethiopia, with a dual function of being exported and consumed locally both raw and processed (Fikre and Mensa, 2021).

Similar to other fruits, the demand for papaya in Ethiopia is rising gradually as a result of dietary changes and the country's fast population growth, but production has not kept up with demand (Fikre and Mensa, 2021). It has also become very popular in recent years due to its ease of cultivation, rapid returns (it fruits earlier than other fruit crops), and adaptability to a variety of soil and climate conditions. It is grown for home consumption and income generation in homestead, smallholder, and commercial production environments. Ethiopian papaya production in the 2018–19 cropping season was 59,205 tonnes, grown on around 4010 hectares of land (CSA, 2019). Despite its importance, the country's papaya productivity is 14 tha-1 (CSA, 2019), which is significantly lower than the global average yield (30 t ha -1) (FAOSTAT, 2019).One of the main obstacles to papaya production in Ethiopia is the lack of improved varieties and limited availability (Ayele et al., 2021).

Papaya grows in tropical to sub-tropical areas all over the world and is mainly propagated by seeds which show wide variability in germination and seedling growth (Mandal and Das, 2021). The majority part of the papaya sowing is done with stored dry seeds, and in this condition, the seed germination is erratic, not uniform, slow, and incomplete, which diminishes the germination percent (Andrade et al., 2008). The desiccation produces stress

in the papaya seeds when the moisture content lowers to 8.0%, being the cause of the seed dormancy or metabolic quiescence (Chumpookam et al., 2012).

Under natural conditions, the germination of papaya seeds is hindered by the presence of aril (sarcotesta), which forms a physical barrier that restricts the diffusion of gases and water into the seeds. Additionally, the presence of phytohormones, which prevent seed germination, induce dormancy, limit embryonic development, and result in low and variable germination which affects the final germination percentage (Sergio *et al*., 2019). The encasedsarcotesta also lowers germination and result in erratic and incomplete germination.

Pretreatment of seeds has significant impact on breaking dormancy, enhancing seed germination and growth development of seedling (Padma et al., 2001). Growing media, is a substrate that gives growing plants the necessary ingredients and physical support has also significant effect on seedling growth and vigor (Desai et al., 2017).The removal of the gelatinous sarcotesta from papaya seeds using chemical priming or other means, as mentioned by Okeyo and Ouma (2008), promotes germination. Combinations of growth media have an effect on both the standard of the seedlings and the germination of papaya seeds (Sarkar and Das, 2021).The impact of KNO_3 priming and growing media on papaya seed germination was examined in a study by Saeka and Das (2021), which found that 3% KNO_3 priming in combination with compost, garden soil, and coco peat in a specific ratio improved seed germination and seedling growth. In a different study, Hossain et al. (2023) found that seedlings treated with gibberellic acid (GA3) outperformed non-treated seedlings. In addition, among the growing media, media containing soil, cocopeat, and vermicompost produced superior results in terms of seed germination and other growth attributes.

Seed germination of papaya is very slow, incomplete, and time consuming. To facilitate seed germination and speed up germination, the right growth medium must be used in conjunction with seed treatment. The media should have appropriate water retention, drainage, and other physical and chemical qualities. As a result, it is preferable to supply soil media or a mixture that meets the requirementsfor maximal seed germination and improved seedling growth. Organic-based media promotes improved root development

when compared to soil-based media, which contains a considerable quantity of field soil (Albadwawi et *al*., 2022).

Pretreatment with potassium nitrate reduced dormancy and improved seed germination (Rachappanavar et al., 2022; Hassan et al., 2023). Gibberellic acidis a plant hormone that is essential for fruit plant growth and yield. It has an effect on plant cell development and cell elongation, particularly in horticultural crops. Nevertheless, under Ethiopian condition, little is known about how priming agents and different growing media affect the germination and development of papaya seedlings. As a result, this proposal is designed with the following objectives.

The objective of this research was to increase production and productivity of papaya by treating with seed priming and different growing media and assessing the effect of seed priming and growing media on papaya seed germination.

2. LITREATURE REVIEW

2.1. Origin and distribution of papaya

Though the exact area of origin is unknown, the papaya is believed native to tropical America, perhaps in southern Mexico and neighboring Central America. It is recorded that seeds were taken to Panama and then the Dominican Republic before 1525 and cultivation spread to warm elevations throughout South and Central America, southern Mexico, the West Indies and Bahamas and to Bermuda in 1616. Spaniards carried seeds to the Philippines about 1550 and the papaya traveled from there to Malacca and India. Seeds were sent from India to Naples in 1626. Now the papaya is familiar in nearly all tropical regions of the Old World and the Pacific Islands and has become naturalized in many areas. Seeds were probably brought to Florida from the Bahamas. Up to about 1959, the papaya was commonly grown in southern and central Florida in home gardens and on a small commercial scale (Morton, 1987).Successful commercial production today is primarily in Hawaii, tropical Africa, the Philippines, India, Ceylon, Malaya and Australia, apart from the widespread but smaller scale production in South Africa, and Latin America. It is also widely cultivated throughout Bangladesh (Morton, 1987).

2.2. Morphology of papaya

Carica papaya is an evergreen, tree-like herb, 2-10 m tall, usually unbranched, although sometimes branched due to injury, containing white latex in all parts. Leaves spirally arranged, clustered near apex of trunk; petiole up to 1 m long, hollow, greenish or purplish-green; lamina orbicular, 25-75 cm in diameter, palmate, deeply 7-lobed, glabrous, prominently veined; lobes deeply and broadly toothed. The leaf contains beta-carotene, calcium, carpaine, fats, flavones, niacin, papain, tannins, and vitamin C (in higher concentration in the leaf than in the fruit). The leaf, unlike the fruit, is not a source of the protein-dissolving enzyme papain, but the latex (sap) in the leaf stem is (Orwa et al. 2009).
The stem is cylindrical, 10-30 cm in diameter at the base to 5-10 cm at the crown, hollow with prominent leaf scars and spongy fibrous tissue. It has an extensive rooting system. Stem density is only 0.13 g cm-3. The single stem provides structural support, body mass, storage capacity, defense substances, height, and competitive ability, and carries a bidirectional flow of water, nutrients, various organic compounds, and chemical and physical signals that regulate root and shoot relations (Morton, J., 1987).
The papaya fruit is pear-shaped with a bright golden-yellow skin. The flesh of the fruit is a brighter orange-yellow, juicy and silky smooth, with a sweet and sour flavor. The shiny

gray or black seeds in the interior of the fruit have a peppery taste and are edible, although they are usually discarded. The fruit yields an enzyme, papain, best known as a digestive aid but most commonly used to "clear" freshly brewed beer. This enzyme is especially concentrated in the fruit when it is unripe (Morton, 1987).

The 5-petalled flowers are fleshy, waxy and slightly fragrant. Some plants bear only short-stalked pistillate (female) flowers, waxy and ivory-white; or hermaphrodite (perfect) flowers (having female and male organs), ivory-white with bright-yellow anthers and borne on short stalks; while others may bear only staminate (male) flowers, clustered on panicles to 5 or 6 ft. (1.5-1.8 m) long.Hermaphrodite (bisexual) papaya flowers are slender and thin and they are attached close to the stem. Male flowers will not be able to become a papaya fruit. Female flowers that are not pollinated will drop off from the tree. Hermaphrodite flowers are most sought after by growers. They are self-pollinating and can give you a papaya fruit (Morton, 1987).Seeds are numerous in central cavities, rounded, blackish, about 0.6 cm in diameter, each enclosed in a gelatinous membrane (aril). (Morton. 1987).The papaya root is predominately a non-axial, fibrous system, composed of one or two 0.5–1.0 m long tap roots. Secondary roots emerge from the upper sections and branch profusely (Jimenez et al, 2013).

2.3. Uses of papaya

Papaya is primarily a fresh-market fruit, and is used in drinks, jams, pectin, candies and as crystallised fruit. Green fruit may be cooked as a vegetable, as may the leaves, flowers and roots (Duke, 1967; Watson, 1997). Papaya has several well-known industrial uses, notably for the enzyme papain (one of its four major constituent cysteine proteinases) (El Moussaoui et al., 2001), which has properties similar to gastric pepsin. Producers induce latex to exude from longitudinal incisions made into unripe fruit; the papain purified from the extract is used in foods, beverages, pharmaceuticals, and other manufacturing (Mabberley, 1998; Wiersema and León, 1999). For example, the food industry uses papain in brewing, manufacturing baby food, and producing proteins for human and animal consumption. Papain is also used to shrinkproof wool and silk, and in the bating process to make leathers more pliable. For some applications however, synthetic enzymes and enzymes from other sources are displacing the use of the natural papain (Watson, 1997; ETA, 2001). The latex from papaya has been used in manufacture of chewing gum. Oil from the fruit’s many (200-1000) more or less spheroidal seeds (c. 2-5 mm × 3.5-6 mm)

(Sharma and Singh, 1975), and other components of fruit and leaves have been used in cosmetics and soap (Quenum, 2001).

Papaya constituents contribute to human nutrition and health. Vitamins A and C from one medium papaya (edible portion 350 g) exceed the Dietary Reference Intakes established by the U.S. Food and Nutrition Board (Inst. Medicine, Natl. Acad. Sci.) for adult minimum daily requirements (CRN, 2001), and papaya is a good source of the minerals K, Mg and B (Hardisson et al., 2001).

Papaya has traditional and modern medical and dental uses; fruits, seeds, latex, and extracts have been used for treating at least forty human conditions, and are being investigated for others (Lewis and Elvin-Lewis, 1977; Mezhlumyan et al., 2003; Petitto, 2004). Papain is used in preparation or manufacturing of adjuvants and reagents for antibiotics or vaccines; chymopapain is a biologic used for treatment of herniated disks in the spine (Quenum, 2001; Mezhlumyan et al., 2003).

Contact with latex derived from abraded green fruits and plant parts or extracts that contain papain or other proteinases may harm unprotected skin, but can also be used in healing wounds (Mezhlumyan et al., 2003). Tissues of papaya (including leaves and roots) which contain cyanogenic glycosides (Olafsdottir et al., 2002; Seigler et al., 2002) and tannins may provoke adverse reactions if consumed in quantity. Papaya enzymes may be injected for medical purposes. However, Moneret-Vautrain et al. (1985) have described the allergenic potential of injected chymopapain extracts up to 1% of the population may have an adverse reaction. Injection may also evoke immune responses to papaya's other known cysteine proteinases, i.e. papain, caricain, and glycylendopeptidase (Dando et al., 1995). The reactions to the fruit, pollen, and papain are mediated by an IgE mechanism (Soto-Mera et al., 2000).

2.4. Propagation method of papaya

Papaya is usually propagated by seeds. The seed in papaya is enclosed in a gelatinous sarco-testa (outer seed-coat or aril) formed from the outer integument of the ovule. Freshly harvested papaya seeds show slow, erratic and incomplete germination (Yahiro, 1979; Palanisamy and Ramamoorthy, 1987) even in seeds from which the sarcotesta has been removed (Yahiro and Oryoji, 1980) indicating that papaya seed germination is problematic.

The cause (s) of low germinability of papaya seeds is still far from being understood. Several pre-sowing treatments have been attempted to improve papaya seed germination.

Removal of sarco-testa (Chow and Lin, 1991); soaking in growth regulators (Tawfik, 2002); in potassium nitrate (Montejo et al., 2002); in magnetized water (Espinosa and Fonseca-Rubio, 1997); in leaf extract and powder, (Ananthakalaiselvi and Dharmalingam, 1998); temperature extremes (Salomao and Mundim, 2000; stratification (Yahiro, 1979); and in vitro germination (Bhattacharya and Khuspe, 2001) treatments have been conducted with only partial inhibition relief.

Cultivation of papaya is hindered by problems due to the inherent heterozygosity and dioecious nature of the crop. Papaya seedlings produced sexually through seed germination show considerable variability in commercial population and being dioecious, the desirable sex type of the produced papaya seedlings must be known to the grower before transplanting to the field to avoid the need for removal of undesirable males, thus saving time and labor. The multiplication of selected papaya trees is thus left to chance when seed produced seedlings are used. Vegetative propagation becomes imperative for the production of standard varieties from the most outstanding local types, those developed through breeding programs or those that are seedless.

2.5. Papaya growth and development

Under appropriate conditions of water availability, light, oxygen, air temperature, and humidity, papaya seeds undergo epigeal germination emergence is typically completed in 2–3 weeks [Fisher 1980]. Primary leaves of young seedlings are not lobed but become so after the appearance of the second leaf. Papaya leaves of adult plants are simple, large, and palmate. In tropical conditions, approximately two leaves emerge at the apex of the plant in a 3/8 spiral phyllotaxy every week (Fisher 1980). Leaf life commonly spans for 3–6 months under tropical conditions and persistent scars remain on the trunk as they abscise. The loss of leaves on the lower section of the plant and the continuous emergence of new ones at the apex give the canopy a sort of umbrella shape that casts a considerable amount of shade. The papaya plant develops very fast, taking 3–8 months from seed germination to flowering (juvenile phase) and 9–15 months for harvest (Paterson et al. 2008). The plant can live up to 20 years; however, due to excessive plant height and pathological constraints, the commercial life of a papaya orchard is normally 2–3 years. (Jimenez et al. 2013).

2.6. Seed priming

Seed priming is a process by which seeds are induced into a state of pre-germinative metabolism by controlled rehydration to increase germination rates and germination vigor. Priming applied to commercial seed lots is widely used by seed technologists to enhance seed vigor in terms of germination potential and increased stress tolerance. Priming can be also valuable to seed bank operators who need improved protocols of ex situ conservation of germplasm collections (crop and native species). Depending on plant species, seed morphology and physiology, different priming treatments can be applied, all of them triggering the so-called 'pre-germinative metabolism' (Paparella et al., 2015).

Seed priming hastens the germination process and enhances the rate of seedling emergence even under extreme climatic conditions and in problem soils. Seed priming is categorized into different types, viz. hydropriming, osmopriming, halopriming, hormonal priming, and biopriming, and provides extensive crop benefits. Seed priming techniques can deal with detrimental conditions in fragile lands such as drought, heat stress, salinity, nutrient stress and several environmental stresses (Devika et al., 2021). Priming exposes seed to stimuli, in response to which a set of interlinked biochemical changes occurs such as activation of enzymes, synthesis of growth-promoting substances, metabolism of germination inhibitors and repair of cell damage (Chatterjee et al., 2018).

2.6.1. Effect of seed priming on seed germination and growth

High quality seeds play an important role in successful crop production. Rapid germination and emergences are essential for successful crop establishment, for which seed priming could play an important role. Seed priming is a pre-sowing strategy for influencing seedling development by modulating pre-germination metabolic activity prior to emergence of the radicle and generally enhances rapid, uniform emergence and plant performance to achieve high vigor and better yields (McDonald, 2000). During priming, seeds are soaked in different solutions with high osmotic potential so that pre-germinative metabolic activities proceed, while radicle protrusion is prevented and then seeds are dried back to the original moisture level.

Harris et al.(2007) reported that seed priming led to better establishment, growth, earlier flowering, increase seed tolerance to adverse environment and greater yield in maize. The

beneficial effects of seed priming have been demonstrated for many field crops such as wheat, sweet corn, mung bean, barley, lentil, cucumber etc. (Sadeghian and Yavari, 2004). Rehman et al., (2011) reported that seed priming is a cost effective technology that can enhance early crop growth leading to earlier and more uniform stand with yield associated benefits in many field crops including oilseeds. Various seed priming techniques have been developed which include hydro-priming, halo-priming, osmo-priming and hormonal priming. Priming applications contribute to significant improvement in seed germination and seedling growth in vegetables (Dursun and Ekinci, 2010).

2.6.2. Effects of different growing media on seed germination and growth

Use of suitable growing media or substrates is essential for production of quality papaya. It directly affects the development and later maintenance of the extensive functional rooting system. A good growing media would provide sufficient anchorage or support to the plant, serves as reservoir for nutrients and water allow oxygen diffusion to the roots and permit gaseous exchange between the roots and atmosphere outside the root substrate (Abad et al., 2002). Nursery potting media influence quality of seedlings produced (Agbo and Omaliko, 2006). The quality of seedling obtained from a nursery influences re-establishment in the field and the eventual productivity of an orchard (Baiyeri, 2006).

A suitable growth medium and its proper application are pivotal to supply mechanical support to the seedlings and water and minerals for the proper development of the plants (Radha*et al.* 2018). Growing medium has a direct impact on seed germination, growth, and vigor of papaya seedling. A proper growth media dispenses adequate support to the seedling, and allows gaseous interchange between roots and the atmosphere.

The effect of growing media on papaya seed germination and seedling growth has been reported by several authors. For example, Sarkar and Das (2021) reported primh agent in combination of growing media affected seed germination and growth of papaya seedlings. In another study by Hossain et al. (2023) indicated that GA3 (priming agent) and growing media impacted the growth and seedling growth characteristics of papaya.

3. MATERIALS AND METHODS

3.1. Description of study area

The experiment was conducted at Wolkite University College of Agriculture and Natural resource horticulture laboratory (the priming) and the germination test was conducted in the green house (Biotechnology department) from march 28 to April 21The study site is situated at 158 km away from Addis Abeba to south west direction. It also located about 7.8°-8.5°N latitude and 37.5°-38.7°E longitude.

3.2. Experimental materials

3.2.1. Papaya variety and source

For the study, local papaya seeds collected from local market, seed extracted and used for the study.

3.2.2. Treatments and experimental design

Experimental treatments consisted of nine treatment combinations of growing medium (sand, farm yard manure, coffee husk, red soil, black soil and poultry manure) and seed priming agents (KNO_3 and GA3). The experiment was conducted in complete randomized design (CRD) with three replications (Gomez and Gomez, 1984) in the green house. A detail treatment combination is presented in Table 1. Seedlings were grown on growing media filled polythelyne bags.

Table 1. Description of treatments used for the study

Treatment	**Description (priming and growing medium combination)**
T1	50% FYM + 25% red soil + 25% sand
T2	3% KNO_3 + 50% sand + 50%FYM
T3	GA3 (1ppm) + 50% coffee husk +50% sand
T4	3%KNO3 + 60% FYM + 40% red soil
T5	GA3 (1ppm) + 60% FYM + 40% black soil
T6	3%KNO3 + 100% red soil
T7	GA3 (1ppm) + 100% black soil
T8	3%KNO3 + 50% forest soil + 50% poultry manure
T9	GA3 (1ppm) +50% FYM + 25% poultry manure +25% red soil

FYM, farmyard manure; GA_3, gibberellic acid; KNO_3, potassium nitrate

3.2.3. Experimental procedures

For treatments that receive priming either with KNO_3 or GA_3, priming was done in petridishes at the horticulture laboratory of Wolkite University. Each priming consisted of fifty papaya seeds. Then depending on the priming agent the seeds were primed at 3% (weight/volume) $KNO_3$and 1%GA3 (1ppm) for 24 hours in an aerated filter at room temperature (25°C). After priming for prescribed duration, seeds were given three surface washings with distilled water and dried back to moisture level of 11% under shaded condition for 12 hours under room temperature and the seeds were made ready for further use (Basra et al., 2005).

For each polythelyne bag 5 seeds were sown, a total of ten polythelyne bag were used for each treatment and is replicated three times. Then seed sowing was done at1 cm deep in polythene bag and polythelyne bags of 10 cm ×10 cm was used for the experiment. The germination study was done under greenhouse condition. The pots were irrigated instantly after seed plantation and repeated each day till the final emergence. After the accomplishment seed sowing, the pots were regularly irrigated regularly once every 2 days.

3.4. Data collected

Germination parameters

Germination percentage (G %) is an estimate of the germinability of the population of seeds (ISTA (2015). Germination was observed daily following the Association of Official Seed Analysts (AOSA, 1990) method. Germination percentage /germinability (GP) (%) measures germination capacity (ISTA, 2015) and was computed as shown below

$$G\%) = \frac{N_g}{N_t}$$

Where N_g is the number of germinated seeds and N_t is the total number of seeds

Mean Germination Time (MGT) (day)**:** Mean germination time is a measure of the rate and time spread of the germination. It indicates time spent to germinate or emerge. Following formula was used to calculate the mean germination time (Ellis and Roberts, 1981):

$$\mathrm{MGT\ (day)} = \frac{\sum \mathrm{D_n}}{\sum \mathrm{n}}$$

Where, n is the number of seeds, which were germinated on day D, and D is the number of days counted from the beginning of germination.

Peak germination value for germination (PV) (% day^{-1}): It is the accumulated number of seeds germinated at the point on the germination curve at which the rate of germination starts to decrease and determined as suggested by Czabator (1962):

$$PV = \max\left(\frac{G_1}{T_1}, \frac{G_2}{T_2}, \ldots . \frac{G_k}{T_k}\right)$$

Where, Ti is the time from the start of the experiment to the *i*th interval, *Gi* is the cumulative germination percentage in the i^{th} time interval, and *k* is the total number of time intervals.

Germination value (G value): for daily germination counts, germination value (G value) is computed as suggested by Czabator (1962):

$$GV = PV \times MDG$$

Where, PV is the peak value, and MDG is the mean daily germination percentage from the onset of germination.

The time to get 50% germination (T_{50}): indicates that how much time was taken for half of the seeds to germinate. T_{50} calculated using the following expression (Farooq, 2005).

$$\mathrm{T_{50}\ (day)} = \mathrm{t_i} + \frac{\left(\frac{\mathrm{N}}{2} - \mathrm{n_i}\right)(\mathrm{t_j} - \mathrm{t_i})}{\mathrm{n_j} - \mathrm{n_i}}$$

Where, N is the final number of germination and n_i, n_j cumulative number of seeds germinated by adjacent counts at times t_i and t_j when $n_i < \frac{N}{2} < n_j$.

The time to get 90% germination (T_{90}): indicates that how much time was taken for 90% of the seeds to germinate. T_{90} was calculated using the following expression (Farooq, 2005).

$$\mathrm{T_{90}\ (day)} = \mathrm{t_i} + \frac{\left(\frac{\mathrm{N}}{10} - \mathrm{n_i}\right)(\mathrm{t_j} - \mathrm{t_i})}{\mathrm{n_j} - \mathrm{n_i}}$$

Germination Index (GI): It is the rate of germination in terms of the total number of seeds that germinate in a time interval and estimated as:

$$\mathrm{GI\ (day)} = \sum_{\mathrm{i=1}}^{\mathrm{k}} \frac{\mathrm{N_i}}{\mathrm{T_i}}$$

Where, T_i is the time from the start of the experiment to the i^{th} time interval, N_i is the number of seeds germinated in the i^{th} time interval (not the accumulated number, but the number corresponding to the i^{th} interval) and k is the total number of time intervals.

Coefficient of velocity of germination (CVG); is a measure used in seed germination studies to quantify the rate of germination.

$$CVG = N_1+N_2…….Ni/100\times N_1T_1+….+NiTi$$

Where N is the number of seeds germinated every day and T is the number of days from seedling corresponding to N.

Mean daily germination (MDG); calculated as the percentage of full seed germination at the end of the test divided from all of the cumulative full seed germination percentage on any day divided by the number of days to reach this percentage

$$\mathbf{MDG} = \sum G/D$$

Seedling growth parameters

Seedling length (SL) (cm)

Seedling length (cm) was taken from five normal seedlings randomly taken from each treatment on each replication is recorded at 34 days of sowing. The seedling length was measured from the base to the tip of the primary leaf.

Number of leaves per seedling

Number of leaves per seedling was recorded from each experimental unit from five randomly selected seedling at the 34^{th} days of sowing. The mean of the five plants was used for statistical analysis.

Vigor index (VI)

Vigor index (VI) is an important parameter for determining fast and uniform emergence and seedling establishment under a wide range of field conditions (Mondo et al., 2013).Seedling vigor index (VI) was calculated by using the below formula as suggested by Abdul-Baki and Anderson (1973) expressed in whole number.

$$\text{Vigor index} = \text{Germination \%} \times \text{Seedling Length (cm)}$$

3.5. Data analysis

Analysis of variance (ANOVA) for germination parameters and growth parameters was computed following the procedure of PROC GLM for CRD design using SAS software version 9.2. Treatment mean comparison was carried out using the procedure of least significant difference (LSD) test at a 5% level of probability.

4. RESULT AND DISCUSSION

4.1. Germination parameters

Analysis of variance showed that treatments significantly ($P < 0.001$) influenced germination percentage (G %), mean germination time (MGT), mean germination rate (MGR), coefficient of velocity of germination (CVG) and germination index (GI) (Table 2).

Table 2. Mean squares from analysis of variance for selected germination parameters

Source	Df	G%	MGT (day)	CVG (%)	GI (day)
Treat	8	953.00***	11.52***	0.88***	0.95***
Error	18	64.00	0.94	0.08	0.04
R^2		0.87	0.84	0.82	0.90
CV (%)		13.48	5.36	5.21	11.57
Mean		59.33	18.12	5.58	1.83

R2, coefficient of determination; CV, coefficient of variation; G%, germination percentage; MGT, mean germination time; CVG, Coefficient of velocity of germination; and GI, germination index

Germination percentage (G %)

The study revealed that the germination percentage (G %) of seeds across different treatments ranged from 18.66% to 80%. The highest G% was recorded in treatment T2, which involved 3% potassium nitrate (KNO3) combined with 50% sand and 50% farmyard manure (FYM), resulting in an 80% germination rate. Following closely was treatment T1, which consisted of 50% FYM, 25% red soil, and 25% sand. T1 achieved a G% of 77.33%. Although T2 had a slightly higher germination rate, the statistical analysis indicated that the difference between T1 and T2 was not significant. This suggests that both treatments are comparably effective in promoting seed germination.

T1, which did not involve seed priming, was nearly as effective as T2, which included seed priming with KNO_3. The slight difference in germination rates (80% for T2 and 77.33% for T1) was not statistically significant, highlighting that the addition of KNO_3 for seed priming does not drastically enhance germination compared to the mixture of FYM, red soil, and sand.

These results have important practical implications for agricultural practices. Farmers and seed companies can achieve high germination rates using either method. For those who

may not have access to or prefer not to use chemical seed priming agents, the combination of FYM, red soil, and sand (T1) provides a viable and effective alternative. This can be particularly beneficial in regions where chemical inputs are limited or where organic farming practices are preferred.

In agreement with the present findings, a previous study by Sarkar and Das (2021) reported that papaya seeds primed with KNO_3 and grown in a mixture of 50% coco peat, 25% compost, and 25% garden soil showed the best results concerning germination percentage. This study also suggested that different growing media have a significant influence on the germination percentage of papaya seedlings. The current study supports this observation, demonstrating that the choice of growing media significantly impacts germination outcomes, with certain combinations performing markedly better than others.

Conversely, the lowest G% was recorded in treatment T8, which involved seed priming with 3% KNO_3 combined with 50% forest soil and 50% poultry manure, resulting in an 18.66% germination percentage (Table 3). This indicates that the combination used in T8 was significantly less effective in promoting seed germination compared to all other treatments.

Mean germination time (MGT)

Mean germination time (MGT) is a measure of the time it takes for seeds to germinate, focusing on the day at which most seeds have germinated. The highest MGT was obtained from T8 (3% KNO3 + 50% forest soil + 50% poultry manure), indicating that seeds in this treatment took the longest time to germinate. This was followed by T6 (3% KNO3 + 100% red soil). The MGT decreased for treatments T5, T7, T2, T3, and T4, suggesting that seeds in these treatments germinated more quickly (Table 3).

Coefficient of velocity of germination (CVG)

The coefficient of velocity of germination (CVG) gives an indication of the rapidity (speed) of germination (Jones and Sanders, 1987). Its value increases when the number of germinated seeds increases and the time required for germination decreases. In this study, the highest CVG was recorded for treatments T5, T7, T2, T3, T4, and T9, which did not statistically differ from each other. This indicates that seeds in these treatments germinated the fastest. T6 and T1 followed, showing slightly lower but still high CVG values. The lowest CVG was recorded in T8 (4.48%), confirming that this treatment resulted in the slowest germination rate (Table 3).

Table 3. Effect of seed priming treatments and growing media combination on seed germination G%, MGT, CVG and GI papaya seedling

Treatment	G%	MGT (day)	CVG (%)	GI (%)
T1	77.33ab	19.22b	5.21b	2.44a
T2	80.0a	16.92c	5.91a	2.12ab
T3	58.67cd	17.49c	5.74a	2.07bc
T4	60.67cd	17.25c	5.82a	2.07bc
T5	61.33cd	16.46c	6.08a	2.01bc
T6	62.0cd	19.77b	5.08b	1.98bc
T7	50.0d	16.45c	6.08a	1.72cd
T8	18.66e	22.33a	4.48c	1.56d
T9	65.33bc	17.19c	5.83a	0.48e
SE (d)	6.53	0.79	0.24	0.17
LSD (5%)	13.72	1.67	0.50	0.36

G%, germination percentage; MGT, mean germination time; CVG, coefficient of velocity of germination; and GI, germination index. Means in a column with same letter do not significantly differ at 5% probability.

Germination index (GI) (%)

The germination index (GI) is an essential parameter that combines the percentage and time of germination, providing an estimate of the time it takes for a certain germination percentage to occur. In this study, the GI ranged from 0.48% (T9) to 2.44% (T1). Accordingly, the highest GI was observed in treatment T1 (2.44%), followed by T2 (2.12%), with no statistically significant difference in GI between these two treatments. Treatments from T3 to T6 exhibited moderate GI values. However, the lowest GI was recorded in T9, where seeds were primed with gibberellic acid (GA3) (1 ppm) in grown in 50% farmyard manure (FYM), 25% poultry manure, and 25% red soil growing media.

The high GI values observed in T1 and T2 indicate that seeds in these treatments germinated rapidly, achieving a high germination percentage in a relatively short time. This suggests that the combination of factors present in T1 and T2, such as the composition of soil amendments or any potential seed priming, significantly accelerated the germination process. Conversely, the low GI in T9 indicates that seeds in this treatment took longer to germinate and/or achieved a lower germination percentage within the same time frame.

Analysis of variance showed that treatments significantly ($P < 0.001$) influenced time to 50%germination, time to 90% germination, mean daily germination (%), G value (Table 4)

Table 4. Mean squares from analysis of variance for T50, T90 MGD, peak value for germination and G value

Source of variation	df	T50 (day)	T90 (day)	(MGD)	Peak value for germination	G value
Treat	8	17.01***	20.11*	1.01***	2.70***	17.39***
Error	18	1.06	7.85	0.05	0.02	0.91
R^2		0.88	0.53	0.90	0.98	0.89
CV		6.18	12.87	14.15	4.95	15.88
Mean		16.63	21.78	1.57	2.87	6.02

T50, time to 50% germination; T90, time to 90% germination; MGD, mean daily germination (%); G value, germination value

Time to 50% germination

Time to 50% germination indicates that how much time was taken for half of the seeds to germinate (Farooq, 2005). The maximum T50% (22.3333) was recorded from T8 (3%KNO3 + 50% forest soil + 50% poultry manure). This indicates that seeds in this treatment took the longest time to 50% germination it also indicate it has significant difference from all other treatments except T9 (GA3 (1ppm) +50% FYM + 25% poultry manure +25% red soil) . While the lowest (15.0667) T50% was obtained from T7 (GA3 (1ppm) + 100% black soil). This indicates that seeds in this treatment took the shortest time to 90% germination. Treatments T2, T3, T4, T5 and T7 also have not significantly different from each other, but they are significantly different from treatments. T6, T3 and T4 also have not significantly different from each other. The last one is T1 and T6 have not significantly different from each other (Table 5). Ali *et al.*,2020 and Farooq *et al.*,2005 also documented differences in tomato cultivars' germination parameters in response to priming with KNO3.

Time to 90% germination

The time to get 90% germination indicates that how much time was taken for 90% of the seeds to germinate (Farooq, 2005). The maximum T90% (25.26) was recorded from T6 (3%KNO3 + 100% red soil). This indicates that seeds in this treatment took the longest time to 90% germination while the lowest (17.96) T90% was obtained from T7 (GA3

(1ppm) + 100% black soil) But T6, T8, T1, T9, T3 and T4 have not significant difference from each other treatment. T7, T2, T3, T4 and T5 also have not significant difference from each other treatment. This shows that seeds in those treatments took the shortest time to 90% germination (Table 4).

Table 5. Effect of priming agents and growing media combination on T50, T90, MGD, Peak vale and G value

Treat	T50 (day)	T90 (day)	MGD (%)	Peak value	G Value
T1	18.08b	23.82ab	2.28ab	3.12bc	6.48b
T2	15.21d	20.38bcd	2.35a	3.89a	9.18a
T3	15.70cd	21.68abcd	1.31ed	3.1bc	6.63b
T4	15.54cd	21.34abcd	1.55de	2.73dc	6.06bc
T5	15.22d	18.26cd	1.14f	3.69a	7.60ab
T6	17.25bc	25.26a	1.70cd	2.39e	4.44c
T7	15.07d	17.96d	1.34def	2.89dc	6.61b
T8	22.33a	24.43ab	0.52g	0.66f	0.54d
T9	15.28a	22.87abcd	1.96bc	3.34b	6.65b
SE (d)	0.84	2.29	0.18	0.12	0.78
LSD (5%)	1.76	4.81	0.38	0.24	1.64

T50, time to 50% germination; T90, time to 90% germination; MGD, mean daily germination (%); G value, germination value

Mean daily germination (%)

Mean daily germination (%) indicates the average number of seeds that sprout or begin to grow each day over a specific period of time. The maximum MGD (2.35) was obtained from T2 (3% KNO_3 + 50% sand + 50%FYM), while the lowest (0.52) MGD was obtained from T8 (3%KNO3 + 50% forest soil + 50% poultry manure) But treatment T2 is significantly different from all other treatments except T1 (50% FYM + 25% red soil + 25% sand) and T8 have significantly different from other treatment. T6, T7 and T4 also have not significantly difference. T1 and T9 have not significantly difference. T9 and T6 have not significantly difference. T5 and T7 have not significantly difference (Table 5).

Peak value

Peak germination value for germination (PV*)* the accumulated number of seeds germinated at the point on the germination curve at which the rate of germination starts to decrease and determined as suggested by Czabator (1962). The maximum peak value (3.89) was obtained from T2 (3% KNO_3 + 50% sand + 50%FYM), while the lowest (0.66) peak value was obtained from T8 (3%KNO3 + 50% forest soil + 50% poultry manure) But T2

have not significantly different from all other treatments except T5 (GA3 (1ppm) + 60% FYM + 40% black soil). T8 have significant difference from all other treatment. T6 also have significantly different from other treatment. The last one is T7 and T4 have not significantly different (Table 5). Improved performance of tomatoes due to seed priming with KNO3 was also reported by previous studies in different tomato genotypes with different KNO3 levels (M. Ali, T. Javed, R, 2020).

Germination value

Germination value indicates the quality of seeds based on their ability to germinate under specific conditions. The highest germination value (9.18) was obtained from T2 (3% KNO_3 + 50% sand + 50%FYM), while the lowest (0.54) germination value was obtained from T8 (3%KNO3 + 50% forest soil + 50% poultry manure) But T2 have not significantly different from all other treatments except T5 (GA3 (1ppm) + 60% FYM + 40% black soil).T1, T3, T4, T9 and T5 have not significantly different. T6 and T4 also have not significantly different. T8 have significantly different from all other treatments (Table 5).

4.2. Growth parameters

Analysis of variance showed that treatments significantly ($P < 0.001$) influenced shoot length, leaf number and vigor index (Table 6).

Table 6. Mean squares from analysis of variance for seedling length, leaf no and vigor index

Source	df	Seedling length	Leaf no.	Vigor index (VI)
Treat	8	48.58***	12.17***	429216.7***
Error	18	3.02	0.70	12097.942
R2		0.88	0.89	0.940363
CV		15.13	11.80	15.17751
Mean		11.48	7.10	724.6948

Seedling length

The highest seedling length (16.23) was obtained from T2 (3% KNO_3 + 50% sand + 50%FYM), while the lowest (5.91) seedling length was obtained from T8 (3%KNO3 + 50% forest soil + 50% poultry manure) But T2, T4 and T5 have not significantly different.

.T1 and T9 have not significantly different. T8, TT6 and T3 also have not significantly different. T6, T7 and T3 have not significantly difference(Table 6). Our findings endorse the results of (Taiz L, Zeiger E, 2002), who documented that seed priming had positive effect on radicle length.

Leaf number

The highest leaf number (9.67) was obtained from T4 (3%KNO3 + 60% FYM + 40% red soil), while the lowest (3.4) leaf number was obtained from T8 (3%KNO3 + 50% forest soil + 50% poultry manure) But T4, T5 and T1 have not significantly different. T1, T2 and T1 have not significantly different. T6 and T3 have not significantly different. T7 and T3 have not significantly different. T8 have significantly different (Table 6). Priming significantly increased leaf number of rape seed as compared to un-primed seeds (Adnan M, *et al*, 2020).

Vigor index

The highest vigor index (1295.6) was obtained from T2 (3% KNO_3 + 50% sand + 50% FYM) while the lowest (109.65) vigor index was obtained from T8 (3%KNO3 + 50% forest soil + 50% poultry manure) But T2 have significantly different from all other treatments. T1, T4 and T5 have not significantly different. T3, T6 and T7 have not significantly different.T8 have significantly different from all other treatments. T9 have significantly different from all other treatments.

Table 7. Effect of priming agents and growing media combination on seedling length, leaf number and vigor index of papaya seedlings

Treat	Seedling length (cm)	Leaf no.	Vigor index
T1	13.93ab	8.47abc	1077.87b
T2	16.23a	8.2bcd	1295.6a
T3	7.27de	5.67ef	424.72d
T4	15.67a	9.67a	951.17b
T5	15.64a	9.0ab	956.27b
T6	7.83de	5.27f	484.75d
T7	9.46cd	6.93de	474.44d
T8	5.91e	3.4g	109.65e
T9	11.41bc	7.33cd	747.79c
SE (d)	1.42	0.68	89.8
LSD (5%)	2.98	1.44	188.7

5. CONCLUSION AND RECOMMENDATION

This research has demonstrated that priming and the choice of growing media significantly influence papaya seed germination. The finding suggest that priming methods and appropriate choice of growing media can enhance germination percentage and reduce the mean germination time and also plays a crucial role in supporting healthy seedling development. In some of the parameters like germination percentage (G%), The highest result was recorded in treatment T2 resulting in an 80% germination rate, mean germination time (MGT) The highest result was obtained from T8, mean germination rate (MGR), coefficient of velocity of germination (CVG) In this study, the highest result was recorded for treatments T5, T7, T2, T3, T4, and T9 which doesn't have data result difference and germination index (GI) the highest result was observed in treatment T1 (2.44%), followed by T2 (2.12%) there is a significant effect on the results.The highest value in the most of germination and the time it takes for germination value was recorded from treatment(T2), which involved 3% potassium nitrate (KNO3) combined with 50% sand and 50% farmyard manure (FYM). The selection of appropriate growing media plays a crucial role in germination of papaya seed for example (T1), which did not involve seed priming but also it closely was as effective as the primed ones in many of the parameters next to T2. In opposite of treatment1, treatment 8 which is primed with 3%KNO_3 and 50% forest soil and 50% poultry manure was combined but yet resulted the lowest in many of the parameters. These results shows that growing media is essential for the growth and germination of of papaya seed and By optimizing these early stage interventions, growers can improve the efficiency and sustainability of papaya production.Overall it is recommended that seed priming with 3%KNO_3 along with growing media of sand and farm yard manure(FYM) in equal proportion could be beneficial practice for improving papaya seed germination and seedling growth if the priming agent is available. For farmers who don't get the chance for the availability of the priming agents, treatment(T1) which is the combination of Farm yard manure, Red soil, and Sand is more productive and successful next to the primed treatment(T2). Further research should explore the long term effects of these treatments on papaya plant growth and yield.

6. REFERENCES

Agbo CU, Omaliko CM (2006). Initiation and growth of shoots of GongronemalatifoliaBenth stem cuttings in different rooting media. Afr. J. Biotechnol. 5:425-428.

Albadwawi MAOK, Ahmed ZFR, Kurup SS.2022. A comparative evaluation of aquaponic and soil systems on yield and antioxidant levels in basil, an important food plant in Lamiaceae. Agronomy 2022; 12(12): 3007. doi: 10.3390/agronomy12123007

Ananthakalaiselvi, A. and Dharmalingam, C. (1998). Soaking/pelleting with botanicals as a cheap technology to improve germination and vigor of papaya seeds (Carica papaya L.) cv. Co.-2. South Indian Horticulture, 46: 132-134.

Andrade M, Ayala J, Alia I, Rodríguez H, Acosta C, López V. Effect of germination promoters and substrates in the development of papayo seedlings. Revista de la Facultad de Agronomía—LUZ. 2008;25:617-635

AOSA (Association of Official Seed Analysts). 2005. Rules for testing seeds. J. Seed Technol., vol. 12, pp. 101–112, 1990.

Association of Official Seed Analysts (AOSA), "Rules for testing seeds," Journal of Seed technology, vol. 12, pp. 101–112, 1990.

Ayele L, Etissa E, Dagnew A, Assefa W, Kebede G, Girma M, Firde K, Ayalew M (2017). Development of Hermaphrodite Papaya (Carica papaya L.)Varieties for Production in Ethiopia. Acad. Res. J. Agri. Sci. Res. 5(7): 561-569

Baiyeri KP (2006). Seedling emergence and growth of pawpaw (carica papaya) grown under different coloured shade polyethylene. Int. Agrophys. 20:In press.

Banik, S., and S. Chanda. 1992. Airborne pollen survey of Central Calcutta, India, in relation to allergy. Grana 31: 72-75.

Basra, S. M.A., M. Farooq, R. Tabassam, N. Ahmad, "Physiological and Biochemical Aspects of Pre-Sowing Seed Treatments in Fine Rice (Oryza sativa L.)," Seed Science & Technology, vol. 33, no. 3, pp. 623–628, 2005

Bhattacharya, J., and Khuspe, S.S. (2001). In vitro and in vivo germination of papaya (Carica papaya L.) seeds.ScientiaHorticulturae, 91: 39-49

Blanco, C., N. Ortega, R. Castillo, M. Álvarez, A.G. Dumpierrez and T. Carillo. 1998. Carica papaya pollen allergy. Ann. Allergy Asthma &Immunol. 81: 171-175.

Castillo, R., J. Delgado, J. Quiralte, C. Blanco and T. Carillo. 1996. Food hypersensitivity among adult patients: Epidemiological and clinical aspects. Allergol.Immunopathol. (Madrid) 24: 93-97.

Chatterjee, N., Sarkar, D., Sankar, A., Sumita, P. A. L., Singh, H. B., Singh, R. K., et al. (2018). On-farm seed priming interventions in agronomic crops. Acta Agric. Slov. 111, 715–735. doi: 10.14720/aas.2018.111.3.19

Chow, Y.J., and Lin, C.H. (1991).pHydroxybenzoic acid as the major phenolic germination inhibitor of papaya seed. Seed Science and Technology, 19 167- 174

Chumpookam J, Huey L, Ching S. 2012. Effect of smoke-water on seed germination and seedling growth of papaya (Carica papaya cv. Tainung No. 2). HortScienc;47(6):741-744

CSA (Central Statistical Agency of Ethiopia) 2019. Report on Area and Production of Major Crops. Agricultural Sample Survey.Volume I, Statistical Bulletin 589. Addis Ababa, Ethiopia. p.13.

Czabator, F. J., "Germination Value: An Index Combining Speed and Completeness of Pine Seed Germination," Forest Science, vol. 8, pp. 386–396, 1962.

Czabator, FJ. 1962. "Germination Value: An Index Combining Speed and Completeness of Pine Seed Germination." *Forest Science* 8 (4): 386–96.

Dando, P.M., S.L. Sharp, D.J. Buttle and A.J. Barrett. 1995. Immunoglobulin E antibodies to papaya proteinases and their relevance to chemonucleosis. Spine 20: 981-985.

Desai A, Panchal B, Trivedi A, Prajapati D. Studies on seed germination and seedling growth of papaya (Carica papaya L.) CV. madhubindu as influenced by media, GA3 and cow urine under net house condition. Journal of Pharmacognosy and Phytochemistry 2017; 6(4): 1448–1451.

Devika OS, Singh S, Sarkar D, Barnwal P, Suman J and Rakshit A (2021) Seed Priming: A Potential Supplement in Integrated Resource Management Under Fragile Intensive Ecosystems. Front. Sustain. Food Syst. 5:654001. doi: 10.3389/fsufs.2021.654001

Duke, J.A. 1967. Darien Survival Manual.Battelle Memorial Institute, Columbus, Ohio. 80 pp

Dursun, A. and Ekinci. M. 2010. Effects on different priming treatments and priming durations on germination percentage of parsley (Petroselinumcrispum L.) seeds.Agricultural Sciences. 1(1): 17-23.

Ellis, R. A.and E. H. Roberts. 1981. The Quantification of Ageing and Survival in Orthodox Seeds. Seed Science and Technology, vol. 9, pp. 373–409, 1981.

Ellis, RH, and EH Roberts. 1981. "The Quantification of Ageing and Survival in Orthodox Seeds." *Seed Science and Technology* 9: 373–409.

Espinosa, A.V. and Fonseca-Rubio, R. (1997). Soaking in water treated with electromagnetic fields for stimulation of germination in seeds of pawpaw (Carica papaya L.) cv. Maradol.Centro Agricola, 24: 36-40

FAOSTAT (Food and Agriculture Organization Corporate Statistical Database). 2019. World Papaya Production Status. Food and Agriculture Organization of the United Nations, Statistical Division.Available online at http://www.fao.org/faostat/en/#d ata/QC/visualize.

Farooq, M., S. M. A. Basra, B. A. Saleem, M. Nafees, and S. A. Chishti, . 2005. Enhancement of Tomato Seed Germination and Seedling Vigor ByOsmopriming," Pak. J. Agri. s., vol. 42, pp. 3–4.

Fikre, G. and Mensa, A. 2021.Evaluation of improved hermaphrodite papaya (Carica papaya L.) varieties at Arba Minch, Southern Ethiopia. Int. J. Agril. Res. Innov. Tech. 11(2): 69-71. https://doi.org/10.3329/ijarit.v11i2.57257

Gomez, K.A. and Gomez, A.A. 1984. Statistical Procedures for Agricultural Research (2nd Ed.). Wiley-Inter Science Publication,) New York, USA.

Hardisson, A., C. Rubio, A. Baez, M.M. Martin and R. Álvarez. 2001. Mineral composition of the papaya (Carica papaya variety Sunrise) from Tenerife island. Eur. Food Res. Technol. 212: 175-181.

Harris, D. 2006. 'On-farm' seed priming. A key technology to improve the livelihoods of resource-poor farmers in marginal environments (extended version). DFID/PSP information booklet, CAZS Natural Resources, University of Wales, Bangor, UK.

Hossain, F., Islam N., Ali, S., Kayes, A., and Choudhury, S.. 2023. GA3 and growing medium influence on papaya seed germination and seedling growth. Trends in Horticulture (2023) Volume 6 (2).doi: 10.24294/th.v6i2.3263

ISTA (International Rules for Seed Testing).2015. The International Seed Testing Association, Bassersdorf., vol. 215, 2015.

ISTA, International Rules for Seed Testing, %e International Seed Testing Association, Bassersdorf, Switzerland, 2015

Jones, K. and Sanders, D., 1987. The influence of soaking pepper seed in water or potassium salt solutions on germination at three temperatures. Journal of Seed Technology, 11, 97–102.

Mabberley, D.J. 1998. The Plant-Book: A Portable Dictionary of the Higher Plants, 2nd Ed., rev. printing. Cambridge Univ. Press, Cambridge, U.K. 858 pp.

Mandal, P. and Das, A. 2021.Effect of Tea as a Potting Substrate on Germination and Seedling Growth of Papaya Seeds. IJAEB: 14(04): doi: 10.30954/0974-1712.04.2021.2

Mezhlumyan, L.G., T.D. Kasymova and P.Kh. Yuldashev. 2003. Proteinases from Carica papaya latex. Chem. Nat. Compounds 39: 223-228

MoA (Ministry Of Agriculture). 2020. Crop Variety Register. Issue No. 23. Plant Variety Release, Protection and Seed Quality Control Directorate. Addis Ababa, Ethiopia

Mondo, V.H.V, Cicero, S.M., DouradoNeto, D., Pupim, T.L. and Neves Dias, M.A.N. 2013. Seed vigor and initial growth of corn crop. Journal of Seed Science 35(1): 64-69.

Moneret-Vautrin, D.A., M. Benoist, M.C. Laxenaire, A. Croizier and J.L. Gueant. 1985. Allergy to chymopapain: Value of predictive tests before chemonucleosis. Ann. Fr. Anesth. Reanim.4: 313- 315.

Montejo, L. A., Sanchez, J.A. and Munoz, B. (2002).Increasing germination in papaya seeds by applying pre-germinative hydration-dehydration treatments.CultivosTropicales, 23: 27-31.

Morton, J.F. (1987). Papaya.In Fruits of warm climates (pp. 149-173). Miami, FL: Julia F. Morton

Moussaoui, A., M. Nijs, C. Paul, R. Wintjens, J. Vincentelli, M. Azarkan and Y. Looze. 2001. Revisiting the enzymes stored in the laticifers of Carica papaya in the context of their possible participation in the plant defence mechanism. Cell.Molec. Life Sci. 58: 556-570.

Olafsdottir, E.S., L.B. Jørgensen and J.W. Jaroszewski. 2002. Cyanogenesis in glucosinolate-producing plants: Carica papaya and Caricaquercifolia. Phytochemistry 60: 269-273.

Orwa et al. (2009) „Carica papaya" Agroforestry Database: a tree reference and selection guide version 4.0

Palanisamy, V. and Ramamoorthy, K. (1987). Seed germination studies in papaya. Progressive Horticulture, 19: 253-255

Pandit, V. K., ShanthaNagaraja and Sinha J. P. 2001. Improving papaya (Carica papaya) seed gammadion and seedling growth by pre-sowing treatments. Ind. J. Agri. Sci., 71 (11): 704-6.

Paparella S, Araújo SS, Rossi G, Wijayasinghe M, Carbonera D, Balestrazzi A. 2015.Seed priming: state of the art and new perspectives. Plant Cell Rep. 34(8):1281-93. doi: 10.1007/s00299-015-1784-y. Epub 2015 Mar 27. PMID: 25812837.

Quenum, B.M. 2001. Business Opportunities in Africa.Freeze-dried papain production plant.Africabiz 1 (20): December 15, 2000 – January 14, 2001. http://businessafrica.net/africabiz/arcvol1/is20front.php

Rachappanavar V, Padiyal A, Sharma JK, Gupta SK.2022. Plant hormone-mediated stress regulation responses in fruit crops-a review. ScientiaHorticulturae; 304: 111302. doi: 10.1016/j.scienta.2022.111302

Radha, T.K., Ganeshamurthy, A., Mitra, D., Sharma, K., Rupa, T.R. and Selvakumar, G. 2018. Feasibility of substituting coco peat with rice husk and saw dust compost as a nursery medium for growing vegetable seedlings. The Bioscan, 13(2): 659-663.

Rana, G., Deb, P., Dowarah, B. and Sushmitha, K. 2020. Effect of Seed pre-.treatment on Seed Germination and Seedling Growth of Papaya. Int. J. Curr. Microbiol. App. Sci., 9(4): 1066-1071.

Sarkar, P. and Das, A. 2021.Effect of Potassium Nitrate Priming and Different Growing Media on Papaya Seed Germination. IJAEB, 14(03): 453-459.

Ranal, MA, Santana DG, WR Ferreira, and Mendes RC. 2009. "Calculating Germination Measurements and Organizing Spreadsheets." *Brazilian Journal of Botany* 32: 849–55.

Sadeghi, H., Khazaei, F., Yari, L. and Sheidaei, S. 2011. Effect of Seed Osmopriming on Seed Germination Behavior and Vigor of Soybean (Glycine max L.).ARPN Journal of Agricultural and Biological Science. 6(1): 39-43.

Salomao, A.N. and Mundim, S.C. (2000).Germination of papaya seed in response to desiccation, exposure to subzero temperatures and gibberellic acid. Horticulture Science, 35: 904-906.

Sarkar, P. and Das, A. 2021. Effect of Potassium Nitrate Priming and Different Growing Media on Papaya Seed Germination. International Journal of Agriculture, Environment and Biotechnology. doi. 10.30954/0974-1712.03.2021.22

Sarkar, P. and Das, A. 2021.Effect of Potassium Nitrate Priming and Different Growing Media on Papaya Seed Germination. IJAEB, 14(03): 453-459.

Sarkar, P. and Das, A.2021. Effect of Potassium Nitrate Priming and Different Growing Media on Papaya Seed Germination. International Journal of Agriculture, Environment and Biotechnology Citation: IJAEB: 14(03): 453-459. Doi. 10.30954/0974-1712.03.2021.22

SAS Institute. 2011. Statistical analysis software (SAS) user's guide. SAS Institute, Cary, NC, 2011.

Sergio Rodriguez, Iramis Vargas, AsterioHijuelo, Frederique Loumeto, Juan J. Silva, Jorge Pérez, Quirino Arias, Yanexis Fonseca, Yarisbel Gómez, Michel Baldoquín and DaliannisOliva. 2019. Seed Dormancy and Germination. doi: 10.5772/intechopen.88012

Serrano L.A.L. and Cattaneo, L.F. 2010 The cultivation of papaya in Brazil. Rev. Bras. Fruit. 32(03): 657-959.

Sharma, B.M., and P. Singh. 1975. Diagnostic characters of seeds of Carica papaya L. – an adulterant of black pepper of commerce. Quart. J. Crude Drug Res. 13: 69-76.

Soto-Mera, M.T., M.R. López-Rico, J.F. Filgueira, E. Villamil and R. Cidrás. 2000. Occupational allergy to papain. Allergy 55: 983-984

Tawfik, A.A. (2002). Effects of planting date, propagation medium and presowing seed treatments and seed longevity on germination and development of Solo papaya seedlings.Zagazig Journal of Agricultural Research, 29: 99-113.

Watson, B. 1997. Agronomy/Agroclimatology notes for the production of papaya. Soil and Crop Evaluation Project.Ministry of Agriculture, Forests, Fisheries and Meterology, Australia.

Wiersema, J.H., and B. León. 1999. World Economic Plants: A Standard Reference. CRC Press, Boca Raton, Florida.

Yahiro, M and Oryoji, Y. (1980).Effects of gibberellin and cytokinin treatments on the promotion of germination in papaya, Carica papaya L., seeds.Memoris of the Faculty of Agriculture, Kagoshima University, 16: 45-51

Yahiro, M. (1979).Effects of seedpretreatments on the promotion of germination in papaya, Carica papaya L. Memoris of the Faculty of Agriculture, Kagoshima University, 15: 49-54.