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Seed Production Technology in Papaya Red Lady Variety in Sirohi District, Rajasthan

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Papaya (*Carica papaya L.*) is a globally important tropical fruit crop valued for its nutritional, medicinal, and economic significance. Efficient seed production is a cornerstone of papaya cultivation, enabling the propagation of high-yielding and disease-resistant varieties. This paper discusses the latest advancements in seed production technology for papaya, focusing on key aspects such as parent selection, pollination techniques, seed extraction, and post-harvest seed treatment. Special attention is given to the dioecious and gynodioecious nature of papaya, highlighting strategies for achieving optimal seed quality and maintaining varietal purity. The role of controlled pollination, including manual and insect-aided methods, is examined in enhancing seed set and uniformity. Additionally, the paper explores seed extraction techniques, fermentation methods for pulp removal, drying protocols, and storage conditions to maintain seed viability and vigor. Advances in biotechnological tools, including molecular markers for gender identification and breeding efforts, are also discussed as innovative solutions to improve seed production efficiency. This comprehensive overview aims to provide insights for researchers, breeders, and farmers to enhance papaya seed production, ensuring sustainable cultivation and global food security.

Key words: Papaya, seed production, isolation, quality, selfing

Introduction

Papaya (*Carica papaya* L.) is a tropical fruit native to Tropical America and belongs to the family Caricaceae. It is a diploid species (2n=2x=18) with a basic chromosome number of x=n=9. Previously, 31 species of *Carica* were reported, but recent taxonomic revisions supported by molecular evidence have revealed genetic distances between papaya and other related species. Some species previously classified under *Carica* are now categorized under the genus *Vasconcella* (Badillo, 2002). Its sweet, juicy fruit is not only a rich source of essential nutrients such as vitamins A, C, and E, but also contains significant amounts of dietary fiber, antioxidants, and papain, a proteolytic enzyme with numerous industrial and medicinal applications.

Papaya typically begins flowering 3–6 months after transplanting. Early identification of desirable plants at the seedling stage is crucial for establishing orchards with suitable designs. In subtropical regions, dioecious varieties like Pusa Nanha and Pusa Dwarf are favoured for their dwarf stature and high yield. In contrast, gynodioecious varieties are

preferred in tropical regions due to their greater yield potential. However, the inability to determine the sex of seedlings before planting remains a significant challenge. In papaya, sex expression is governed by a single gene with three alleles, which exhibit pleiotropic effects.

Papaya's economic importance extends beyond its fresh fruit market, as it is also processed into products such as juices, jams, and dried fruit. Furthermore, papaya seeds, leaves, and latex have traditional medicinal uses and applications in cosmetics and pharmaceuticals. The crop's ability to produce fruit year-round, coupled with its relatively short cultivation cycle, makes it highly desirable for small-scale farmers and commercial plantations alike. Papaya is a polygamous nature of the fruit plant. Therefore, it is imperative to know the cross combination and its segregation ration in the next generation prior to initiate the crossing programme. The cross following cross combination and their segregations are given in Table 1.

Table 1. Sex segregations of papaya in F_1 generation

Cross combination	Segregation ratio		
	Male	Female	Hermaphrodite
Female x male	1	1	
Female x hermaphrodite		1	1
Hermaphrodite (selfed)		1	2
(Hermaphrodite x male		1	1

Papaya seed standard

Quality of the seed largely depends on the different parameters of the seed standards followed during seed production and while packaging seed for the marketing in the name of foundation and certified seed. Papaya seed standards are provided in Table 2.

Table: 2 Standards for papaya seeds

Parameter	Standard
Physical Purity	≥ 98%
Germination Percentage	≥ 80%
Moisture Content	≤ 8% (for general storage) or ≤ 6% (for long-temperature storage)
Genetic Purity	≥ 99% (for certified seeds)
Seed Health	Free from seed-borne pathogens and diseases like PRSV (Papaya Ring Spot Virus)
Seed Size	Uniform size and weight, indicative of healthy and viable seeds
Seed Treatment	Treated with fungicides (e.g., Thiram or Captan) or bio-control agents
Isolation Distance	Minimum 1,000 meters from other papaya varieties to maintain genetic purity
Viability Duration	Viable for 1–2 years under proper storage conditions

Floral Biology

Papaya is a polygamous plant three basic types of flowers viz staminate, pistillate and hermaphrodite (bisexual). Of these, only pistillate is stable, whereas flowers of hermaphrodite and male vary in sex expression under different environmental conditions.

Staminate flowers: Staminate flowers serve as pollinators. These plants show 1 to 1.5 m long flower stalks hanging out from trunk. The individual flower is small, tubular and contains stamens only.

Pistillate Flowers: Pistillate flowers are large, yellow bone singly or in group of three in the leaf axils close to the trunk. The flowers have fine large twisted and fleshy petals that surround an ovary, which swells and develops into papaya fruit The fruits developed from pistillate flower are spherical to oblong shaped having thick, yellow to orange coloured flesh

in different cultivars with large to small cavity in which numerous rounds wrinkled black seeds are attached.

Hermaphrodite or bisexual flowers: It has both male and female organs. Individual flowers are 3.5 to 4.5 cm long with tubular base that widens into goblet shape and then spreads out into 5 thick yellow-coloured recurred petals. In between these petals, male organs i.e. stamens are present and female organs containing oblong ovary which develops into cylindrical fruits.

1. The dehiscence of anther takes place 24 hours before anthesis in all the species of Carrica, the dehiscence in staminate and hermaphrodite flowers takes place between 10 to 12 hours before anthesis.
2. High temperature and low humidity hasten the time of anther dehiscence.
3. In papaya, high percent pollen germination can be achieved with 5 percent sucrose solution. Papaya pollen can be stored up to 5 years without losing the viability if proper conditions are created for storing. The floral diagram is presented below:
4. Stigma become receptive one day prior to anthesis and it remains receptive two days after flower anthesis.
5. The best hour of the crossing is between 8-10 hours in the forenoon during rainy days.

Table 3: Isolation Distance for Papaya Seed Production (*Red Lady* Variety)

Seed Type	Isolation Distance	Purpose
Foundation Seeds	1,000 meters	Ensures genetic purity by preventing cross-pollination with other varieties.
Certified Seeds	500 meters	Maintains seed quality by reducing contamination risk from other plants.
Hybrid Seeds	1,000 meters	Avoids genetic mixing between hybrids and non-hybrid or local varieties.
Research Breeding Lines	1,200 meters	Ensures the integrity of breeding lines for research purposes.

Pollination

If a papaya plant is inadequately pollinated, it will bear a light crop of fruits lacking uniformity in size and shape. Therefore, hand-pollination is advisable in commercial plantations that are not entirely bisexual. Sometime, seedless fruit may observe in the areas where gynodioecious varieties/hybrids are dominating in the cultivation. These seedless fruits are due to lack of proper pollination and fertilization

Criteria for Seed Production in Papaya Red Lady Variety

Producing high-quality seeds for the *Red Lady* papaya variety requires meticulous planning and adherence to scientific methods to ensure genetic purity, viability, and germination potential. Below is an updated and comprehensive list of criteria for seed production, along with relevant references:

1. Selection of Parent Plants: Use healthy and true-to-type hermaphroditic parent plants, as they are the primary seed source for maintaining the *Red Lady* variety's characteristics. Avoid plants showing any symptoms of viral diseases like papaya ring spot virus (PRSV), as this can compromise seed quality and genetic integrity (Nath & Chakraborty, 2001). Conduct genetic verification using molecular markers, if available, to confirm the authenticity of parent plants (Ming *et al*., 2007).

2. Pollination Management: *Red Lady* is a gynodioecious variety, consisting of hermaphroditic and female plants. Hermaphroditic plants are ideal for seed production due to their consistent fruit and seed quality. Manual pollination can be performed in a controlled environment to ensure genetic purity and prevent cross-pollination. Minimize open pollination, especially in regions with other papaya varieties, to avoid unwanted pollen contamination (Kumar & Kumawat, 2014).

3. Isolation Distance: Maintain an isolation distance of **1,000 meters** from other papaya varieties to prevent cross-pollination and maintain genetic purity (ICAR Guidelines, 2011). In areas with limited space, use physical barriers like netting or plant windbreaks to limit pollen movement.

4. Crop Management Practices

Soil Requirements: Plant in well-drained soils with a pH range of 6.0–7.5 (Nakasone & Paull, 1998).

Nutrient Management: Apply a balanced fertilizer regimen, including nitrogen (N), phosphorus (P), and potassium (K), along with micronutrients like zinc and boron.

Irrigation: Ensure regular irrigation to maintain adequate soil moisture, especially during flowering and fruiting stages.

Pest and Disease Control: Implement integrated pest management (IPM) strategies to control pests like fruit flies, aphids, and mealybugs. Regularly monitor for fungal diseases and viral infections (Thakare *et al.*, 2020).

5. Rogueing: Conduct regular rogueing to remove off-type, diseased, or weak plants. This ensures the genetic purity of the seed crop and prevents the spread of diseases.

6. Fruit Harvesting for Seed Extraction: Harvest fruits from healthy hermaphroditic plants at full maturity. Mature fruits are identified by uniform yellowing of the skin and firmness. Avoid harvesting overripe or immature fruits, as they may produce seeds with poor viability (Marler & Discekici, 1997).

7. Seed Extraction and Processing: Extract seeds by cutting open ripe fruits and separating them from the pulp. Remove the gelatinous aril layer surrounding the seeds by washing them thoroughly. Fermentation for 24–48 hours can also help in aril removal. Dry seeds under shade to maintain their viability. Avoid direct sunlight, which can damage seed quality (Krishnapillai & Thakare, 2015).

8. Seed Treatment: Treat seeds with fungicides like Thiram or Captan (2–3 g/kg of seed) to prevent fungal infections during storage. Use priming techniques such as hydro-priming or Osmo priming to enhance seed germination and vigor (Singh et al., 2018).

9. Seed Storage

- Store seeds in airtight containers or vacuum-sealed bags under cool, dry conditions.
- Maintain a storage temperature of **10–15°C** and relative humidity of **30–40%** to prolong seed viability (Ellis et al., 1985).
- Periodically test stored seeds for germination and viability to ensure quality.

10. Seed Quality Testing: Perform seed quality tests in accordance with the International Seed Testing Association (ISTA) standards.

Ensure the following minimum standards:

- **Germination percentage:** ≥80%
- **Physical purity:** ≥98%
- **Moisture content:** ≤8% (ISTA, 2020).

Planting and Spacing of Papaya Red Lady Variety

The following planting and spacing recommendations for the *Red Lady* papaya variety are based on scientifically-backed practices and expert agricultural guidance **National Horticulture Board (NHB), India** (2023).

Spacing Recommendations

Standard Spacing:

- **1.8 m x 1.8 m** (6 ft x 6 ft) is ideal for optimal air circulation and sunlight penetration.
- Suitable for general cultivation and accommodates approximately 3,000 plants per hectare.

High-Density Planting:

- **1.5 m x 1.5 m** (5 ft x 5 ft) is used for intensive cultivation, allowing around 4,400 plants per hectare.
- Requires efficient disease and pest management.

Row Spacing:

1. Maintain **2.0–2.5 m** between rows for easier movement during irrigation, pruning, and harvesting. **University of Florida IFAS Extension (2021)**

Planting Practices

Pit Dimensions:

- Prepare pits of **60 cm x 60 cm x 60 cm**.
- Fill pits with a mixture of topsoil, farmyard manure (10–15 kg per pit), and neem cake (1 kg per pit). **ICAR (Indian Council of Agricultural Research), 2022**

Planting Time:

- Plant at the onset of the rainy season or during dry periods with irrigation facilities.
- Best seasons: Spring (February-March) and Monsoon (June-July). **Thakare, R. *et al.*, (2020).**

Papaya Leaf Curl Virus and Papaya Ringspot Virus (PRSV)

1. Papaya Ringspot Virus (PRSV)

Discovery and Early Observations:

1. PRSV was first identified in the **1920s** in the Caribbean and Florida, where it caused significant damage to papaya crops.
2. The characteristic ring-like spots on fruits gave the disease its name.
3. Initially, the virus was confused with other plant diseases due to its wide host range, especially among cucurbits.

Global Spread:

1. By the mid-20th century, PRSV had spread to most tropical and subtropical regions, including Asia, South America, and Africa.
2. The global movement of infected plants and the presence of aphid vectors (*Aphis gossypii* and *Myzus persicae*) facilitated its rapid spread.

Breakthroughs in Management:

1. In the 1990s, the development of transgenic papaya varieties resistant to PRSV, such as **'Rainbow'** and **'SunUp'**, revolutionized disease management in Hawaii. These were among the first genetically modified crops approved for commercial use.

2. Papaya Leaf Curl Virus (PLCV)

Discovery and Early Observations:

Papaya Leaf Curl Virus was first reported in the **1960s** in India, where it caused severe economic losses in papaya production. It was identified as part of the *Begomovirus* group, transmitted by the whitefly (*Bemisia tabaci*).

Global Spread: Initially confined to the Indian subcontinent, PLCV gradually spread to Southeast Asia, the Middle East, and parts of Africa. Its spread coincided with the increasing prevalence of whiteflies as a major pest in tropical and subtropical regions.

Harvesting, Seed Yield, and Precautions for Red Lady Papaya Variety

The *Red Lady* papaya variety is a high-yielding hybrid known for its sweet, juicy fruits and excellent productivity. Proper harvesting techniques, seed yield management, and precautions are crucial to ensure maximum profitability and quality.

Fruit Harvesting

1. **Maturity Indicators:**

- Fruits are ready for harvest **5–6 months after transplanting** (depending on climatic conditions).
- Look for a **yellowish tinge** at the base of the fruit, which indicates ripening.
- The fruit should feel firm to the touch but not overly hard.

2. **Harvesting Method:**

- Use a sharp knife or pruning shears to cut the fruit along with a short stalk.
- Harvest during the cooler parts of the day (morning or evening) to minimize heat stress on the fruits.

3. **Post-Harvest Handling:**
- Wash the fruits gently to remove latex and dirt.
- Grade the fruits based on size, shape, and color for market readiness.
- Store harvested fruits at **12–14°C** with a relative humidity of 85–90% for prolonged shelf life.

Seed Yield

1. **Seed Production Per Fruit:**
- *Red Lady* papaya fruits yield **500–1,000 seeds per fruit**, depending on size and pollination efficiency.
2. **Seed Collection:**
- Select healthy, disease-free, fully ripe fruits for seed extraction.
- Cut the fruit and scoop out the seeds. Wash them thoroughly to remove the gelatinous sac around the seeds.
- Dry the seeds in a shaded, well-ventilated area until they reach a moisture content of **8–10%**.
3. **Seed Yield Per Hectare:**
- On average, **25–30 kg of seeds** can be obtained from 1 hectare of *Red Lady* papaya plantation if maintained under ideal conditions.

Precautions

1. **During Harvesting:**
- Avoid overripe fruits as they are prone to bruising and microbial decay.
- Handle fruits carefully to prevent mechanical damage or latex burns.
2. **For Seed Production:**
- Ensure proper isolation of *Red Lady* plants (at least **1,000 meters** from other papaya varieties) to maintain genetic purity.
- Remove any plants showing signs of viral infections like PRSV or PLCV to prevent contamination.
3. **Pest and Disease Control:**
- Monitor for pests such as aphids, whiteflies, and mealybugs, as they can transmit viruses.
- Apply integrated pest management (IPM) practices to control infestations without harming beneficial organisms.
4. **Post-Harvest Care:**
- Avoid stacking fruits directly on top of each other to prevent bruising.
- Maintain hygiene during seed extraction to prevent fungal contamination

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