

Chapter – 20

ENHANCING THE FRUIT SET, SIZE AND PRODUCTIVITY OF CUSTARD APPLE VAR. ARKA SAHAN THROUGH ARTIFICIAL POLLINATION

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Introduction

Custard apple (*Annona squamosa* L.) belongs to the family Annonaceae, is one of the important topical fruit crops in India. Custard apple is mainly used as dessert fruit however both the pulp and seeds are also used for medicinal purposes. Locally significant as traditional medicines, custard apples are cultivated commercially for their delectable fruits. In the world custard apple is considered less important economically (Pinto *et al.*, 2005), while in India, it is the most importance fruit of the annonaceous. The Annonaceous fruits originated in tropical America and are widely distributed in tropics and sub tropics. Among annonaceous fruits, custard apple is the most favourite in India. Its plants grow unchecked as a shrubs or hedge plant in areas of Andhra Pradesh, Assam, Bihar, Karnataka, Maharashtra, Madhya Pradesh, Orissa, Rajasthan, and Tamil Nadu. On a very small scale, other annonnas are also grown. Bullock's heart is more commonly found in south India than in north India. It is usually associated with gardens and compounds and not commercial orchards. Cherimoya is mostly restricted to Assam and hills of south India. Atemoya and sour soup are cultivated in some gardens as miscellaneous fruits. Atemoya, cherimoya and Ilaça also provided excellent opportunities for a large-scale exploitation in India. Pollination is the process by which pollen grains are transferred from the male reproductive organs (anthers) of a flower to the female reproductive organs (stigma) of the same or a different flower, leading to fertilization and the production of seeds. Pollination is a crucial step in the reproduction of flowering plants (angiosperms).

Pollination can occur through various mechanisms, including wind, water, and animals. Animal pollination is particularly significant and involves the assistance of animals such as bees, butterflies, birds, bats, and even some mammals. These animals are attracted to flowers by their colors, fragrances, or nectar, and while they feed or move between flowers, they inadvertently pick up pollen grains on their bodies. When they visit another flower of the same plant or a different plant, some of the pollen is transferred to the stigma, allowing for fertilization and the subsequent development of seeds and fruits.

Floral Biology:

Flower Structures: Annona flowers are usually somewhat fragrant, solitary or in short lateral clusters (fascicles). The custard apple flower is hermaphroditic, male and female parts in the same flower and exhibits protogynous i.e. pistils mature before pollen is liberated from anther, suggests that self-pollination is not the rule for annonas. The flowers consist of three green sepals and six petals arranged into two verticals (Pinto *et al.*, 2005). Green outer petals, purplish at the base, oblong, 1.6 centimetres to 2.5 centimetres long, and 0.6 centimetres to 0.75 centimetres wide, inner petals reduced to minute scales or absent (Aluka, 2008). There are numerous stamens; crowded, white, less than 1.6 centimetres long and ovary light green. Styles are white, crowded on the raised axis. Each pistil forms a separate tubercle like small rounded wart-like protuberance, mostly 1.3 centimetres to 1.9 centimetres long and 0.6 centimetres to 1.3 centimetres wide which matures into the aggregate fruit (ICFRA, 2008).

Flowering Time: Flowering starts when the plant is three to four years old, although it may occasionally occur earlier depending upon varieties and environmental conditions (Pinto *et al.*, 2005). Some varieties such as ‘Pink’s Mammoth’, exhibit strong apical dominance, producing few flowers until 5-7 years of age. Other varieties, such as ‘African Pride’, produce an abundance flowers within 2-3 years after planting (George *et al.*, 1995). Normally flowering occurs in spring-early summer (FNA, 1998). In subtropics flowering period extends from spring (February-March) to rainy season (July-August). Custard apple flowers from March to July, Cherimoya flowers from May to June and July to September and Bullocks heart flowers from August to October.

Anthesis: Anthesis starts slowly, with the separation of the apex of the external petals and takes for 6 to 8 h to complete (Pinto *et al.*, 2005).

Stigma Receptivity: Stigma remains receptive from one day before anthesis to about 2-3 hrs after anthesis but it decreased abruptly so by the time of dehiscence stigma turned almost unreceptive and observed protogynous dichogamy.

Pollination: The most favourable period to hand pollinate flowers is in the early morning prior to 11 am. Fruit set is reduced if flowers are pollinated during the hottest period of the day. Hand pollination should not be attempted on days when light rain is falling as fruit set on these days is reduced. Ahmad (1935) reported that the best time for artificial pollination was from 5 am to 8 am and also reported that drier and hotter period adversely affected the fruit set.

Fruit Set: Fruit set can occur as a result of self-pollination, insect-assisted pollination or hand pollination. Low marketable yield is a major problem in various annonaceous types. The reasons for low fruit set are dichogamy, lack of pollinizers and production of flowers without attractive color, poor pollen germination, environmental and tree condition. Fruit set is poor around 2-3% in custard apple which might be due to protogynous flowers.

Artificial Pollination: Artificial pollination of custard apple, is a process in which the transfer of pollen from the male reproductive structures to the female reproductive structures is done manually, typically using a brush or cotton swab. This method is employed when natural pollinators like bees or other insects are insufficient or absent, or when growers want to ensure controlled cross-pollination to improve fruit quality or obtain specific traits.

Why Need Hand Pollination in Custard Apple:

Hand pollination of custard apple may be necessary in certain situations where natural pollination is insufficient or ineffective. The existing of protogyny makes hand pollination a useful tool in development of hybrids, since breeder can select the parents to be crosses and may also improve a full-sib progeny population more quickly than a half-sib one (Pinto *et al.*, 2005).

Lack of Natural Pollinators: Custard apple flowers rely on insects like bees for pollination. However, in some areas, there may be a shortage of natural pollinators due to factors like habitat loss, pesticide use, or environmental conditions. In such cases, hand pollination ensures that the flowers are successfully pollinated and fruit production is not compromised.

Low Pollination Success Rate: Even if natural pollinators are present, custard apple flowers may have low pollination success rates. This can be due to factors like unfavourable weather conditions, poor flower quality, or low pollen viability. Hand pollination allows growers to directly transfer pollen to the female flowers, increasing the chances of successful fertilization and fruit set.

Controlled Cross-Pollination: Hand pollination allows growers to have control over the pollination process and facilitate cross-pollination between specific cultivars or varieties. This enables them to achieve desired traits in the resulting fruits, such as improved flavor, size, or disease resistance. Controlled cross-pollination can also be beneficial for breeding programs or the development of new cultivars.

Improved Fruit Quality and Yield: By hand pollinating custard apple flowers, growers can ensure that only high-quality pollen is used for fertilization. This can lead to improved fruit quality, uniformity, and increased yield. Hand pollination also allows growers to selectively pollinate the best flowers, resulting in larger and more desirable fruits.

Overcoming Self-Incompatibility: Some custard apple cultivars exhibit self-incompatibility, which means that the pollen from the same tree or variety cannot fertilize the flowers effectively. Hand pollination enables the transfer of pollen from a compatible cultivar, overcoming self-incompatibility and promoting fruit development.

Factors Affecting of Hand Pollination:

Several factors can affect the success of hand pollination in custard apple. These factors include:

Timing: Hand pollination should be performed during the optimal time when the female flowers are receptive to pollen. If the pollination is done too early or too late, the chances of successful fertilization decrease. Monitoring the stage of flower development and conducting hand pollination at the right time is crucial.

Pollen Viability: The viability of pollen, *i.e.*, its ability to fertilize the female flowers, is an essential factor. Pollen should be collected from mature male flowers that are shedding pollen. If the pollen is not viable or has low viability, it may not lead to successful fertilization. Proper handling and storage of pollen are important to maintain its viability.

Pollen Source: The source of pollen used for hand pollination can impact the success rate. Using pollen from a compatible custard apple cultivar or variety ensures higher chances of successful fertilization. It's important to choose a pollen source that is genetically compatible with the female flowers to promote fruit set.

Pollination Technique: The technique used for hand pollination can influence the success of the process. Gentle and careful application of pollen to the stigma is important to ensure proper attachment and pollination. The use of a small brush or cotton swab to transfer pollen is a common method, but the technique should be practiced with care to avoid damaging the flowers.

Environmental Conditions: Environmental factors such as temperature, humidity, and light can influence the success of hand pollination. Extreme temperatures or high humidity levels can affect pollen viability and decrease the chances of successful fertilization. Adequate environmental conditions, including moderate temperatures and appropriate humidity levels, promote better pollination outcomes.

Flower Health and Quality: The health and quality of the flowers being pollinated play a role in successful fertilization. Flowers that are damaged, diseased, or have poor reproductive structures may have reduced fertility. Selecting healthy and robust flowers for hand pollination increases the chances of successful fruit set.

Pollen Quantity: Sufficient quantity of pollen is necessary for effective hand pollination. If the quantity of pollen applied to each stigma is inadequate, the chances of fertilization decrease. It is important to ensure that an adequate amount of viable pollen is transferred to each female flower.

Advantage of Hand Pollination in Custard Apple

There are so many advantages of hand pollination are:

1. Increased fruit set of low yielding varieties
2. Manipulation of the harvest time
3. Better quality (size and shape) fruits

The major purpose of hand pollination today is to promote fruit set in lower producing cultivars. In order to generate expensive early or late set fruit, there is also a significant chance to alter flowering and fruit set times. Hand pollination also results in higher-quality fruit, which is more suitable for export markets. Fruit that has been hand-pollinated frequently commands a higher price.

**Steps for Hand Pollination:
Pollen Collection and Storage**

Pollen of fine yellow powder from the custard apple flowers should be collected in a clean dry cup or any similar container during mid to late afternoon. The pollen sacs should have turned creamy-grey in color and should no longer be securely bound together by the time the petals are almost completely open. Pollen sacs that are still developing are whitish and compact. The blooms will quickly release their pollen sacs during hot, low-humidity days. These can be collected by shaking or tapping and rubbing the flowers between the fingers over a piece of paper. The pollen sacs should be placed in a small container and stored at room temperature ($<20^{\circ}\text{C}$) overnight for use in the following morning. In the alternative, the flowers should be spread evenly over shallow tiered trays and left overnight if the pollen sacs do not easily detach from the blossoms. The following morning, the pollen sacs should be separated. Flowers shouldn't be kept in a closed container since the ethylene and moisture buildup will turn the pollen sacs brown and drastically inhibit pollen germination. According to preliminary research, custard apple pollen can only be kept for two to three days at most. The pollen can also be collected directly from the flower in the morning at 6.00-7.00 am

Methods of Pollen Application

A number of methods are available for applying pollen to flowers when hand pollinating custard apples. These methods include pollination guns, puffers and the use of a camel hair brush. All of these techniques are effective when pollen is not strongly diluted with a carrier such as lycopodium (a tan powder made from the spores of club mosses which is highly flammable) or PVC dust. Brush application technique is a most effective method of increasing fruit set and symmetry. The quality of the fruit from this method is only affected when the dilution of pollen falls below 30 per cent. The brush technique produces more reliable results due to a greater amount of pollen applied to the stigmas.

Procedure**The Pollination Procedure Includes**

Dipping a Dry Clean Brush into A Cup Containing Pollen: A natural hair painting brush must be preferred over synthetic fibres, as pollen adhered better on the former type. While pollinating, it would be convenient to place the cup in the shirt front pocket and the petals may be held apart with one hand so that the stigma is easily accessible for evenly applying of pollen on the stigma of about to open flowers.

The Brush is dipped again into the Cup for Pollinating Next Flower: Using the brush technique, flowers can be hand pollinated at the rate of 150-200 flowers per hour with success rates varying between 80-100 per cent. While, using pollination guns the rate can be increased up to 400 flowers per hour but with low fruit set rate.

Pollen Dilution for Hand Pollination

In commercial orchard, hand pollination is normally adopted to increase fruit set percentage. However, to collect sufficient pollen for pollinating an economical number of flowers is very time consuming and tedious job. This can be improved by extending the spread of pollen by using dilutants such as PVC dust, lycopodium and talc. Pollen dilution is a technique used in hand pollination to improve the chances of successful fertilization. In hand pollination, the exact pollen dilution ratio for custard apple depending on factors such as the specific variety of custard apple and the desired outcome. Commonly used materials for pollen dilution include talcum powder or cornstarch. The pollen is mixed with the inert material in a specific ratio to achieve the desired concentration. The ratio can vary, but a commonly used dilution ratio is approximately 1:10, meaning 1 part pollen to 10 parts inert material.

Procedure for Hand Pollination Using Diluted Pollen:

Collect Pollen: Gently tap the mature anthers of the custard apple flower to collect pollen onto a clean container.

Dilute the Pollen: Mix the collected pollen with an inert material (e.g., talcum powder or cornstarch) in the desired dilution ratio. For example, if using a 1:10 dilution, mix 1 part pollen with 10 parts inert material.

Apply the Diluted Pollen: Using a small brush or cotton swab, collect a small amount of the diluted pollen mixture and gently transfer it to the stigma of the flower you wish to pollinate. Carefully dab the stigma to ensure even distribution of the pollen.

Hand Pollinated Variety of Custard Apple Arka Sahan

In 1986, Indian Institute of Horticultural Research, Bangalore initiated work on evolving a less seeded, very sweet custard apple variety with better shelf life. Hence, a large number of inter- and intra-species annona hybrids were developed evaluated, and a hybrid by name 'ArkaSahan' was released in 1997.

Fruits of Arka Sahan are remarkable for scarce small seeds (9/100g fruit weight), sweetness ($>32^{\circ}\text{B}$: 22.8% total sugar), and slow ripening (5-6 days). The pulp is snow-white, mealy and juicy with a mild pleasant aroma. Nutritionally, a 100g pulp of Arka Sahan contains 2.49g crude protein, 42.29mg phosphorus and 225mg calcium compared with 1.33g, 17.05mg and 159mg respectively, in common custard apple. It is an inter-species hybrid developed by hybridizing Island Gem (atemoya) and Mammoth (custard apple). Large numbers of self-fertile flowers are produced by the hybrid. Because the male and female structures of ArkaSahan's flowers mature at separate times and there isn't as much insect and wind pollination as in other annonas, just a small percentage of its blooms (about 1-2%) turn into fruits. Therefore, relying solely on natural pollination will prevent the crop's potential from being realized. In addition to this, hand pollination, which is fairly easy, quick, and affordable, was developed to produce huge, symmetrical fruits in addition to increased output.

Using five distinct pollen sources, hand pollination was attempted in 2003 and 2004 at various times of the day. A better outcome was attained by hand pollinating plants between the hours of 6 and 9 in the morning. Using custard apple (sitaphl / sarifa) pollen instead of ArkaSahan gave excellent results. ArkaSahan fruits developing from pollen of *Annona squamosa* (sitaphal or sarifa) were by far better than those produced from other pollen sources including natural set in respect of fruit set, size and shape. Very high fruit set of 86 per cent was obtained from the pollen of sitaphal while that of ArkaSahan pollen and natural set was 55.2% and 1.4% respectively. Up to 80% of pollinated flowers generate fruits that will ripen till the harvest and weigh roughly 90% more than open pollinated fruits while maintaining the qualities. The size of the ArkaSahan flowers makes hand pollination reasonably simple and quick. 150–200 flowers can be pollinated every hour.

- Hand pollination should be effected in the morning hours before 9.30, as described below.
- Collect Pollen of Custard Apple in a plastic cup from the previous day opened flowers.
- Place the cup in the shirt pocket and dip a clean dry paintbrush (no. 2 or 3) into the cup.
- Using the pollen coated brush evenly smear the pollen on the stigma of ArkaSahan flowers.

Hand pollination is an easy and quick method that yields huge, beautiful fruits with consistent shapes and no loss of culinary qualities, in addition to good fruit set. Therefore, artificial pollination can dramatically enhance fruit output. Since an ArkaSahan tree can start producing 40–45 kg of fruit after eight years, each tree needs roughly 150 hand-pollinated blossoms to produce the estimated 25 tonnes/ha of fruit.

Hand pollinated fruits will be more expensive to buy in the market. Hand pollination is required to produce a commercial crop of Pinks Mammoth and Hillary White custard apples. Pollen from these varieties is not always available at the right time in large enough quantities to set a viable commercial crop. Other varieties, such as African Pride (which produces large quantities of flowers), can be a good source of pollen in these times of pollen shortfall.

Pinks Mammoth and Hillary White Custard Apples

Pinks Mammoth

One popular hand-pollinated custard apple variety is the "Pinks Mammoth" custard apple (*Annona cherimola*). This variety is known for its large fruit size, creamy texture, and sweet flavor. It is named after Mr. Pink, the man who introduced it to Australia. When mature the tree produces significant yields. Hand pollination is often necessary for custard apples because they typically have complex flower structures that require manual intervention for successful fertilization.

Hillary White:

A strain of Pink's Mammoth. The cropping performance is between that of Pink's Mammoth and the African Pride with smooth skin and average fruit shape. More consistent bearer, much sweeter fruit than Pink's Mammoth with average fruit size and shape. Trials were conducted to assess the use of alternative pollen sources. Flowers from African Pride, Pink's Mammoth and Hillary White varieties were harvested mid-afternoon and left overnight. The following morning, the pollen sacs were extracted from the flowers of each of the varieties. Flowers from both Pink's Mammoth and Hillary White were hand pollinated with pollen from Pink's Mammoth, Hillary White and African Pride. African Pride was only pollinated with its own collected pollen, to confirm its pollen viability. African Pride was not pollinated with the other two pollen sources as it usually does not require hand pollination. All pollinated flowers were tagged and the pollen source recorded. Fruit, resulting from the pollination, was assessed at harvest. African Pride pollen is best shows a high level of self-compatibility when using its own pollen for hand pollination. In contrast, varieties such as Pink's Mammoth show a high level of self-incompatibility which results in reduced fruit set and poorer fruit shape. African Pride is therefore the preferred pollen source for most commercial varieties of custard apples.

Precautions during Hand Pollination in Custard Apple Trees:

Timing: Hand pollination should be carried out during the peak flowering period of the custard apple tree. This is usually when the flowers are fully open and receptive to pollination. Observe the tree closely and choose the appropriate time.

Select Healthy Flowers: Choose flowers that are healthy and show no signs of damage or disease. Avoid using flowers that are wilting or have already shed their petals.

Proper Tools: Use a small, clean brush or cotton swab for transferring pollen. This ensures that you don't damage the delicate parts of the flower during the process. Avoid using your fingers as they can introduce contaminants.

Pollen Collection: Collect pollen from the flowers of a healthy donor tree. Gently tap the anthers of the donor flower onto a clean, dry surface, such as a small container or paper. Collect the pollen using your brush or swab.

Pollination Process: Carefully transfer the collected pollen to the stigma of the selected recipient flowers. Gently brush the stigma with the pollen-laden brush or swab, ensuring good contact between the pollen and stigma.

Avoid Cross-Contamination: Take precautions to prevent cross-pollination between different custard apple varieties, especially if you're trying to preserve the purity of a specific cultivar. Clean your tools between pollination sessions to avoid mixing pollen from different trees.

Weather Conditions: Choose a day with calm weather for hand pollination. Wind or rain can interfere with the process by dispersing the pollen or making it difficult to apply it accurately.

Labeling: If you're conducting multiple hand pollinations or working with different varieties, consider labeling the pollinated flowers to keep track of the crosses made.

Sanitation: Maintain good sanitation practices by cleaning up fallen petals and other debris around the tree. This reduces the risk of disease transmission and helps create a clean environment for pollination.

Conclusion:

Hand pollination can be an effective method for ensuring successful fruit set in custard apple varieties. By manually transferring pollen from the male flower to the stigma of the female flower, hand pollination bypasses the need for natural pollinators like bees or insects.

Hand pollination can significantly improve fruit set in custard apple varieties, especially when natural pollinators are limited or absent. By manually transferring pollen, growers can ensure that an adequate amount of pollen reaches the stigma, increasing the chances of successful fertilization and fruit development. Hand pollination allows growers to control the pollination process, ensuring that high-quality pollen is used and reducing the risk of cross-pollination from inferior sources. Hand pollination can be a valuable technique in areas where natural pollinators are scarce or when weather conditions are unfavourable for their activity. In such cases, hand pollination can provide a reliable alternative for achieving successful pollination and fruit set. Hand pollination is a time-consuming and labour-intensive process, requiring manual intervention for every flower. This can be challenging, especially in orchards with a large number of trees. Adequate manpower and planning are necessary to execute hand pollination effectively and additional costs due to the need for labour and management. The cost-benefit analysis should be conducted to evaluate whether the potential increase in yield and fruit quality justifies the investment required for hand pollination.

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