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# Role of pollination in improving productivity of cashew – A review

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**ABSTRACT**

Cashew has become an important nut crop in India owing to its nutritional value and export earnings. The productivity of cashew in India is low because of several reasons and hence India imports raw nuts from other countries to meet the demand of its processing industries. Several studies have shown that inadequate pollination plays an important role in low productivity of cashew in addition to other factors. Hence, it is imperative to understand and address the issue of pollination in cashew to increase the productivity. In this regard, an attempt has been made here to review the research related to pollination in cashew.

**Key words:** Cashew, Inadequate pollination, Productivity, Raw nuts, Role of pollination.

Cashew (*Anacardium occidentale* L.) is an important export crop in the tropics and contributes to social and economic development of number of countries around the world (Bezerra *et al*., 2007; Masawe 2009). According to Jhonson (1973) it is originated from Brazil. During 16th century it was introduced into India, the East Indies and Africa by the Portuguese explorers. Thereafter, exploitation of cashew for its fruits (nut as well as apple) among local people appeared to have been the pattern for more than 400 years in Asia and Africa (Mitchell and Mori, 1987).

Cashew is cultivated over an area of 9.92 lakh ha in India with an annual production of 7.53 lakh tonnes during the year 2013 (FAOSTAT, 2015). The national average productivity stands at 7591 hg / ha (here hg means hectogram and 1 hg=0.1kg) which is considered as very low compared to other important cashew growing countries and is below the world average productivity of 8136 hg/ ha (FAOSTAT, 2015). It is estimated that India requires 1.3-1.4 million tonnes of raw cashew nuts per annum in order to meet the demand of the existing processing capacity. So it imports 50 per cent of raw cashew nuts requirement from other countries (DCR Vision 2030). For instance, during the year 2012, India imported 8.22 lakh tonnes of raw cashew nuts of worth US$ 925286000 (FAOSTAT, 2015).

The average yield in Brazil which is acclaimed as the home of cashew, is only 1577 hg/ha which is far below the world average yield of 7591 hg/ha (FAOSTAT, 2015). Previous studies have pointed out a series of reasons for Brazil's low cashew nut yield, such as lack of soil correction, irrigation and pest control and prevalence of orchards with old trees grown from seeds instead of selected, grafted and productive varieties (Aquino *et al*., 2004; Oliveira 2007; Rossetti and Montenegro 2012). Despite recent progress in these areas, substantial improvement has not been observed in cashew yield. The same is true for cashew productivity in India.

Several studies have shown that inadequate pollination is playing an important role in low productivity of cashew (Reddi 1987; Freitas *et al*., 2002; Holanda-Neto *et al*., 2002) in addition to other factors. Hence, it is imperative to understand and address the issue of pollination in cashew to increase the productivity. In this regard, an attempt has been made here to review the research related to pollination in cashew.

**Flowering behavior :** Cashew is reported to be a cross pollinating tree crop (Pavithran and Ravindranathan, 1974; Free and Williams, 1976; Palaniswami *et al*., 1979). The tree bears male /staminate (Fig1.a) and bisexual / hermaphrodite / perfect/ pistillate flowers (Fig1.b) on the same panicle (Rao and Hassan, 1957; Ascenso and Mota, 1972; Kumaran *et al*., 1976; Thimmaraju *et al*., 1980). However, abnormal flower types have also been reported (Northwood, 1966; Mota, 1973; Kumaran *et al*., 1976; Joseph, 1979). Cashew trees require 4, and even 5 months to complete the sequential anthesis in the panicle (Pavithran and Ravindranathan, 1974). The male flowers provide pollen grains for the female part of bisexual flowers for pollination and fruit set (nuts). Although the total number of flowers in a panicle varies from 200-1600 over a period of 70-90 days of flowering period, only less than 10% of those are bisexual flowers.

**Mode of pollination and fruit set :** The structure of hermaphrodite flower is such that developed stamen is short filamented and only half in length of the style which makes it difficult for self pollination and favours cross pollination. Although close to 85% of the perfect flowers are fertilized

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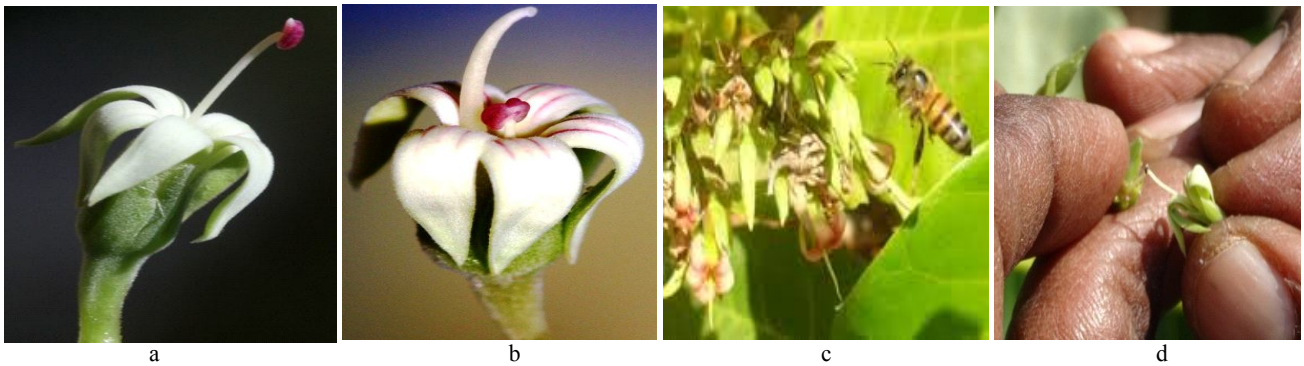

a b c d

**FIG 1:** Types of flowers and pollination in cashew. a-fresh male(staminate) flower with undehisced pink anther, b-fresh hermaphrodite (bisexual/ perfect) flower with long pistil and short stamen, c-honey bee visiting cashew inflorescence (panicle) for effecting open pollination, d-artificial (hand) pollination for producing hybrids.

under standard conditions, only 4-6% of them reach maturity to give fruits, the remaining are shed away at different stages of development. The fruit drop in cashew during the early stages of development is attributed to physiological reasons (Northwood, 1966). Insects attack also plays an important role in immature fruit drop (Pillay and Pillai, 1975). Despite early suggestions that cashew was wind pollinated (Haarer 1954; Aiyadurai and Koyamu 1957; Rao and Hassan 1957), later studies through bagging of panicles (to exclude insects and wind as pollinating agent) and caging / bagging with nylon mosquito nets (allow access to wind but exclude insects) have proven that wind does not has any role and insects play a key role in pollination of cashew (Reddi, 1991; Frietas and Paxton 1996). Further, flies (Roubik 1995), moths (Kevan, 1975) and bees (Heard *et al*., 1990; Freitas and Paxton 1996; Bhattacharya 2004) have been viewed as the major cashew pollinators, but little information is available about the effective pollinators and use of honeybees for pollination purposes (Phoon 1984; Mohamad and Mardan 1985; Freitas 1994). Sundararaju (2000, 2003) reported that in coastal Karnataka, the activities of pollinators on cashew were low. However, two groups of bees *viz*., halictid and honey bees constantly visit fresh flowers. Among them, halictid bee, *Pseudapsis oxybeloides* (Smith) was dominant and mainly collects pollen from male flowers and pollen as well as nectar from hermaphrodite flowers within 2-5 seconds / flower. The other halictid bees observed were *Lasioglossum* sp. and one unidentified species. *Apis cerana indica* F. and *A.florea* F. were common among honeybees whereas *A.dorsata* was very rarely sighted. The stingless bee, *Trigona irridipennis* Smith was found collecting both nectar and pollen. He observed a maximum of 53.6 per cent of hermaphrodite flowers pollinated in field condition on the same day evening of anthesis. As per Frietas (1997) honey bee (*Apis mellifera* L.) and solitary bee (*Centris tarsata* Smith) are the efficient pollinators of cashew in Brazil, the home of cashew.

**Anthesis :** According to Rao and Hassan (1957) the peak anthesis is between 9 -11 am. Hermaphrodite flowers start opening from 9- 10 am and continue till 1 pm. Staminate flowers open from 9 am and continue till about 3 pm. Damodaran *et al*., (1965, 1966) reported that staminate flowers open very early in the morning and continue till about 4 pm. Perfect flowers open mostly between 10 am and 12 Noon. It was found that over 85 per cent of male flowers opened before 11 am while over 80 per cent of perfect flowers opened between 10 am and 1 pm. Wunnachit and Sedgley (1992) in their study at NW Australia observed two peaks of flower opening per day for both types of flower one in the early morning and one around mid day.

**Dehiscence of anthers, pollen viability and stigma receptivity:** The peak period of dehiscence of anthers was from 9.30 to 11.30 am and the rate of dehiscence was slightly higher on the sunny side of the tree till about 10.30 am compared to that on the shady side (Damodaran *et al*., 1965, 1966). According to Rao and Hassan (1957) anther dehiscence starts from 10.30 am and pollen grains remain viable for 48 hrs. The viability of pollen is usually high and it was 93.9% by acetocarmine staining and the stigma becomes receptive one day prior to anthesis and its receptivity stays for two days (Damodaran *et al*., 1966). Aliyu (2007) reported pollen fertility range of 53.77 - 98.94%, in vitro pollen germination range of 23.30 – 44.89% and pollen grain size range of 40.42 - 56.60 µm in clones. Eradasappa *et al*., (2014) reported that pollen fertility ranged from 53.2- 96.4 % in varieties of cultivated species, *Anacardium occidentale* whereas in three wild species *viz*., *A.microcarpum*, *A.othonianum* and *A.pumilum* , it was 92.3 %, 90.5 % and 93.8 % respectively. Studies on *in vitro* germination of pollen were carried out by few researchers. Damodaran *et al*., (1966) reported 36.2% pollen germination *in vitro* condition with 30% sucrose. Nearly two decades later Subbaiah (1984) observed that a medium comprising polyethylene glycol 4000, sucrose, boron and calcium gave 90-95% *in vitro* pollen germination as well as excellent pollen tubes comparable with those found *in vivo*.

**Studies on extent of pollination and fruit set:** Reddi (1987) reported that cashew plants permit about 27% of their well pollinated flowers to develop into fruits. But in nature only 10.5% yield is possible because of under-pollination and this was substantiated by stigmatic- pollen load analysis data. In nature about 25-72% of the stigmas were found unpollinated due to limitation of pollinators leading to lower than potential yields. Further he stated that yield increase of 157.8% is possible if the perfect flowers receive adequate pollen for pollination. Earlier workers also suggested that pollination in nature is inadequate (Rao, 1974; Kumaran *et al*., 1976a). Moreover, on average cashew produces 21.6 pollen grains to pollinate one hermaphrodite flower and hence shortage of fertile pollen grains cannot be considered as a limiting factor for higher yield (Elsy *et al*., 1986). Holanda-Neto *et al*., (2002) suggested that low fruit set in cashew is due to self incompatibility. Wunnachit and Sedgley (1992) reported that less than 40% of the hermaphrodite flowers set fruits and this was followed by high rate of premature fruit shedding.

Sundararaju (2011) conducted studies on extent of pollination and final fruit set. He observed final fruit set to an extent of 24.6% in Bhaskara variety by hand pollination whereas among naturally pollinated flowers, the final fruit set was 10.1% only. He also worked out correlation between number of flowers pollinated/day within a period of 14 days and number of final fruit set observed from manually pollinated flowers/day and found highly significant with positive correlation (r=0.77). Therefore, he suggested that by enhancing the level of pollination, the productivity can be increased. For this presence of adequate active insect pollinators will help rapid transfer of pollens immediately after anthesis. However, this warrants devise of suitable methods for enhancing pollination.

**Self pollination and fruit set in cashew:** Self pollination followed by self fertilization does happen in cashew to a limited extent. This was evident from the experiment conducted at DCR, Puttur where in five panicles each in two varieties *viz*., Bhaskara and Ullal-3 were bagged using cloth bags to prevent insect visits and 2-3 nuts were obtained (Eradasappa, 2012, unpublished). But Bhattacharya (2004) observed zero fruit set in the bagged panicles in a ten randomly selected trees from a cashew plantation at Shantiniketan, India.

**Artificial hybridization in cashew:** Hybridization can expand the gene pool in relation to genes with different adaptive values, as long as the hybrids are able to produce segregating progeny in future generations (Stebbins, 1974). Evidence of hybrid vigour with an increase of up to 153 per cent in the nut yield as compared to plants derived from out crossed pollinations was reported by Damodaran (1975). The prevalence of heterosis in hybrids of cashew with respect to nut yield, nut weight and kernel weight were reported by Manoj and George (1993) and Cavalcanti *et al*., (2000). Hybridization work carried out at several cashew research centers in India (Puttur, Vengurla, Bapatla, Madakkathara and Bhubaneswar) showed that hybrid vigour existed for yield and hybrids were found to perform better than selections in cashew.

A simple and improved technique of hand pollination in cashew has been developed at Directorate of Cashew Research, Puttur (Bhat *et al*., 1998). In this technique panicles that have flower buds which are about to open the next day on male and female parents trees are selected. Next day between 8.00 am and 9.30 am, all male flowers from the selected panicle in the female parent are removed, perfect flowers are emasculated by removing anthers and stigma along with style is enclosed with butter paper roll. Simultaneously freshly opened male flowers are collected from the selected male parents, anthers are allowed to dehisce under partial shade (dehisced anthers are bluish grey) and dehisced anthers are used for pollinating stigmas. The pollinated stigma along with style is re-enclosed with butter paper roll. This technique can be employed for developing hybrids in cashew breeding programmes. Recent hybridization experiments conducted at Directorate of Cashew Research, Puttur (Fig1.d) recorded final fruit set ranging from 3.2-36.9% among 15 cross combinations (DCR Annual Report 2012-13).

**Beekeeping in cashew orchard to enhance productivity:** Since the cashew is dependent on pollination by insects, visitation of bees (halictid bees, honey bees-Fig1.c, stingless bees and solitary bees) to flowers is crucial to increase yield. Five decades ago, Smith (1958) suggested that bees may be used to promote greater pollination based on the experiences in Tanzania. In this regard, African Cashew Initiative and Dr. Kwame Aidoo, a beekeeping expert from the University of Cape Coast Ghana conducted a joint study on the impact of beekeeping on cashew production and results were published in 2013 (www.africancashewalliance.com). The results revealed that cashew farmers in Benin experienced a 200% increase in yield by adopting beekeeping (Apiculture) compared to non adopted farmers. Besides, assisted pollination by deploying beehives gave an average income increase of more than 200% from the cashew plantation alone. Moreover, farmers also gain additional revenue by selling by-products of beekeeping such as honey, propolis and wax which are being preferred by the pharmacies in the region to produce natural medicine. Beekeeping has improved the livelihood of cashew farmers in Ghana and Benin tremendously by increasing yields. It is estimated that by deploying two colonies of bees in one hectare of cashew farm, a farmer will earn about US$ 575 on an average. So cashew growers in India can also adopt beekeeping in cashew cultivation to have adequate pollination and enhance yield, and gain additional benefits from it.

## CONCLUSION

Pollination is very crucial for fruit set in flowering plants. As cashew is highly cross pollinated by insects mainly bees, their activities in cashew plantation play an important role in increasing yield. The hand pollination in cashew is being attempted by the plant breeders to combine desirable features of two varieties of same species into one hybrid (intraspecific/inter-varietal hybridization) or to combine desirable feature from wild species into cultivated species (interspecific hybridization). Many hybrids with desirable traits have been developed by employing this technique. Nevertheless, open / natural pollination mainly through insects plays major role in cashew production as hand pollination in nature for this purpose is an uphill task. It has been evident from review of earlier works of cashew researchers that there is an ample scope to raise the present yields of cashew by supplementing pollination. Hence, learning from the success of beekeeping in Benin and Ghana, pollination can be supplemented by the inclusion of beehives in the cashew orchard to increase the productivity even in Indian conditions.

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