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Breeding in Host Plants of Eri Silkworm for Rearing Suitability

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Abstract

Ericulture is a unique sericulture associated with agricultural, horticultural and forestry plants. Eri silkworm, *Samia ricini* (Donovan) is polyphagous in nature and feeds on over 30 species of host plants. All the food plants are not equally suitable for eri silkworm rearing, and it shows different behaviors when reared on different food plants. However, castor (*Ricinus communis*), kessaru (*Heteropanax fragrans*), cassava (*Manihot utilissima* and *Manihot esculenta*), borkessaru (*Ailanthus excelsa*), barpat (*Ailanthus grandis*), and payam (*Evodia flaxinifolia*) plants are found to be more suitable for commercial Ericulture. Furthermore, variety/genotype influences also have a significant impact on Ericulture productivity and profitability. Hence, the evolution and evaluation of suitable host plant varieties is the main goal of Eri host plant improvement. The major objectives of host plant improvement are the development of a perennial nature with a non-bloomy red type in castor, decreases in cassava leaf anti-nutrient content, potentiating higher rooting ability in barpat, production of a dwarf type plant that is more amenable to pruning in kessaru borkessaru and payam; along with higher leaf yield and quality and better adaptability to diverse climatic conditions. In this view, CEMRTI (Central Eri Muga Research and Training Institute, Central Silk Board) identified some suitable varieties/accessions, such as NBR-1, NBR-2, and NBR-3 in castor, HF-005 and HF-008 in kessaru, MVD-1, H-226 and H-165 in cassava, for ericulture. In this context, the review article provides comprehensive information for improving Eri host plants, which includes host plant botanical description, genetic resources, genetics and breeding methods to take up further research in eri host plant improvement for boosting the Ericulture industry.

Keywords : Barpat, Borkessaru, Castor, Cassava, Eri silkworm, Kessaru, Payam

The Eri silk is commonly known as 'Endi silk' or 'Erandi silk', is produced by *Samia ricini* Donovan. Eri silk is considered, economically, the third most important silk in the world after Mulberry and Chinese Tasar silk (Suryanarayana, 2005). Eri silk constitutes 81.03 per cent of the total non-mulberry raw silk production of 9087 MT in India, which was estimated at 7364 MT during 2021-22 (CSB, 2022). The Eri silkworm belongs to the Saturnidae order of Lepidoptera and is one of the most domesticated, exploited and popular non-mulberry silkworms. There are 19 Eri (genus: *Samia*) species recorded in tropical Asia, three of which, *Samia ricini*, *Samia canningi*, and *Samia fulva*, are reported to be found exclusively in India (Peigler and Naumann, 2003). Seven Eri silkworm (*Samia ricini*) eco-races were collected from various locations in northeast India. The ecoraces are Borduar, Titabar, Khanapara, Nongpoh, Mendipathar, Dhanubhanga, Sille and Kokrajhar. Six pure-line strains of Eri silkworm were isolated from Borduar and Titabor ecoraces. These are Yellow Plain (YP), Yellow Spotted (YS), Yellow Zebra (YZ), Greenish Blue Plain (GBP), Greenish Blue Spotted (GBS) and Greenish Blue Zebra (GBZ). Recently, a new Eri silkworm breed, C-2 has been developed through conventional breeding (Sarmah *et al.,* 2015).

The Eri silkworm is multivoltine and reared indoors 5-6 times a year. Because the Eri silkworm is hardy and disease-tolerant, its productivity per acreage is higher than that of other silkworms. The culture is eco-friendly and low-investment (Patidar *et al.,* 2022).

Eri cocoons are open at one end and thus cannot be reeled. The cocoons are white or brick-red in color. Unlike other silks, only spun silk can be produced from Eri cocoons and hence, the amount of fiber lost during its spinning is very small. Eri silk has a unique appearance and aesthetic appeal. It has a wool-like finish, the look of cotton and the softness of silk, but none of the dazzle or rusting sound associated with other types of silk. It is highly durable and has a specific thermal property, which renders it an alternate fiber to wool (Suryanarayana, 2005). As of date, a number of diversified fabrics (lighter to heavy fabrics, inner wear, dress material, ornamental fabric, thicker fabric like chadder, wall hangings, furnishings and hosiery fabric) have been produced from Eri silk, taking advantage of its strong affinity to dyes and blending properties with other natural and synthetic yarns. The various Eri silk pupa recipes are in high demand in the tribally dominant states of the northeast (Singh and Ahmed, 2017).

It is commonly reared in the northeast Indian states of Assam, Meghalaya, Nagaland, Manipur and Arunachal Pradesh. Most of the production of Eri silk comes from the state of Assam. About 2,94,419 families in Assam are engaged in Ericulture and there are 33,433 hectares of land covered by Eri food plants in government and private farms, with a production of 6573 tons of Eri cocoons and 5275 tons of Eri raw silk in the years 2020-21 (Anonymous, 2021). In recent years, the farmers of several other states, *viz.*, Madhya Pradesh, Andhra Pradesh, Tamil Nadu, Maharashtra, Karnataka, Uttar Pradesh, Bihar, Jharkhand, Gujarat, West Bengal, Orissa and Sikkim, have taken up the Ericulture (Patidar *et al.,* 2022). Now, besides in India, Ericulture is also present in various countries, such as Thailand, Vietnam, China, the Philippines, Nepal, Ethiopia and Cambodia (Kawabe *et al.,* 2012).

Eri silkworm is polyphagous in nature and feeds on a wide range of plants, over 30 species (Choudhury, 1982 and Reddy *et al.,* 1989). The host plants are categorized as primary, secondary and tertiary based upon the degree of acceptance by the larvae, their growth, development and cocoon yield (Bindroo *et al.,* 2007). Castor (*Ricinus communis*) and kesseru (*Heteropanax fragrans*) are considered to be the primary hosts, while tapioca (*Manihot utilissima* and *Manihot esculenta*), payam (*Evodia flaxinifolia*), borkesseru (*Ailanthus excelsa*) and barpat (*Ailanthus grandis*) are secondary hosts and these plants can be used for the commercial production of Eri silk (Sakthivel, 2012). Rest of the plant species like *Ailanthus glandulosa, Ailanthus tryphysa, Artocarpus heterophyllus, Carica papaya, Celastrus monospermus, Cinnamomum cecicodaphne, Cinnamomum glanduliferum, Daucus carota, Ficus benghalensis, Gmelina arborea, Hodgsonia heteroclite, Jatropha curca, Jatropha multifida, Micromelum pubescens, Mechelia champaca, Oroxylum indicum, Plumeria acutifolia, Plumeria rubra, Sapium eugenifolium, Sapium sebiferum, Spathodea companuclata, Terminalia catappa, Zanthoxylum alatum, Zanthoxylum rhesta* and *Zizyphus mauritiana* are tertiary on which the silkworm could complete its lifecycle (Das *et al.,* 2020). Furthermore, Eri silkworm could not complete its life cycle when rear completely with non host plants species such as *Acalypha indica, Morus alba* L., *Morinda citrifolia, Leucaena leucocephala* (Radhika *et al.,* 2017), *Calotropis gigantean, Nerium odourm, Leucaena leucocephla, Parthenium hysterophororum, Annona squamosa, Pongamia pinnata, Sesbania grandiflora,* coconut and banana (Subramanianan *et al.,* 2013), *Acacia ferruginea, Bauhinia purpurea, Bambusa arundinaceae, Bambusa vulgaris, Sapindus emarginatus, Peltophorum ferrugineum, Pongamia pinnata, Samanea saman, Swietenia marophylla, Tabubia argentina, Cassia auriculata, Ficus religiosa, Hardwickia binata, Manilkara hexandra, Simarouba glauca, Acalypha gracilens, Lantana camara* and *Cassia fistula* (Naik and Murthy, 2013).

Castor is an annual plant and has to be grown again every six months for continuous leaf availability, which increases the cost of cultivation and is difficult for small and marginal farmers. Its leaves become sparse during the winter and insect pest incidences are high, which also reduce the leaf yield and quality. Due to ecological adaptation and short seed viability, kesseru is only found in a few pockets of the north-eastern Indian region. In such a case of leaf scarcity, the use of alternate or secondary host plants is required. Ailanthus, a perennial host plant found throughout India, is one of the alternatives to the Eri host plant. Barpat and borkesseru plants of *Ailanthus* species are perennial in nature and leaves are accessible consistently throughout the year (Chowdhury, 2006). Furthermore, pupae from Eri silkworms fed on barpat and borkesseru leaves can be used easily as a source of proteinaceous food, just as pupae from castor-fed silkworms are suitable for human consumption as well as feed for fish, poultry, piggery, cattle and other purposes. The plantations of *Carica papaya*, a tertiary food plant, are also coming up on a large scale in many parts of south India and the leaves can be used productively (Subramanianan *et al.,* 2013; Kavane, 2014 and Radhika *et al.,* 2017).

Fig. 1 : An Illustration of Ericulture benefits from host plants cultivation and Eri silkworm rearing.

The cultivation of host plants offers additional income from their seeds (castor), tubers (cassava), fruits (papaya) and fire woods (borkessaru, barpat, kessaru and payam), while the rearing of Eri silkworms provides delicious pupa for consumption and litter for compost production apart from cocoon production (Fig. 1). Therefore, the development of a module system for Ericulture with compatible host plants is urgently needed for improving Ericulture horizontally in India.

Botanical Description, Genetic Resources, Genetics and Breeding Methods

Castor (*Ricinus communis* L.) : Among all host plants, castor is the most preferred by Eri silkworm. Moreover, about 25-40 per cent of castor foliage can be defoliated (removed) and used for feeding Eri silkworms without affecting oilseed production (Raghavaiah, 2003). Castor is a highly valued and economically important crop for its leaf biomass and non-edible seed oil. The castor is widely cultivated in the arid and semi-arid regions of the world (Govaerts *et al.,* 2000). Castor is one of the best and most appropriate host plants for commercial rearing and cocoon harvesting. The northeast states play a pivotal role in utilizing castor leaves for Eri silkworm rearing and contribute a major percentage of the total Eri silk production of the country (Sarkar and Borpuzari, 2022). All natural types of castor are diploid (2x) in nature with 2n=20 chromosomes (Hagerup, 1932). Based on secondary bivalent

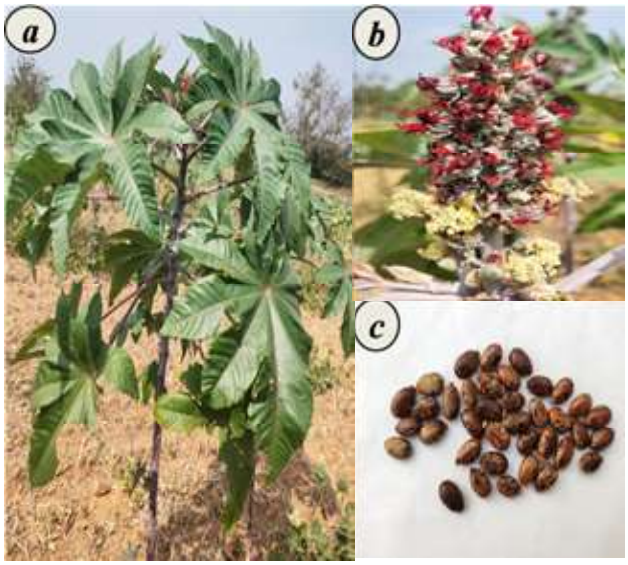

Fig. 2 : Castor plant

association, castor was reported to be a secondary balanced polyploid with a basic chromosome number of x=5 (Richharia, 1937; Kurita, 1946 and Jacob, 1957). Ten pachytene bivalents are clearly distinguished morphologically in diploid castor (Jacob, 1956 and Paris *et al.,* 1978). Castor has the lowest DNA C-value (2C=0.46 pg) known among the Euphorbiaceae species (Leitch *et al.,* 2019) and has a moderately sized genome with ~350 Mbp (Armuganathan and Earle, 1991). A cultivar, Hale, was used to sequence the castor genome (Chan *et al.,* 2010).

Castor is a cross-pollinated species belonging to the family Euphorbiaceae and genus *Ricinus*, which is considered to be monotypic and *Ricinus communis* is the only species, which includes many polymorphic types. The cultivated types are dwarf annuals. The leaves are large, often dark glossy green, and about 15 to 45 centimeters long, with a long petiole. The leaves are palmate, with five to eleven lobes and prominent veins on the undersurface (Fig. 2a). The leaves are alternate, except for two opposite leaves at the node immediately above the cotyledons. Depending on the level of anthocyanin pigmentation, the leaf color ranges from light green to dark red. In some cases, the leaves start off as a dark reddish purple or bronze when young, gradually changing to a dark green, sometimes with a reddish twinge, as they mature (Weiss, 2000).

Castor is monoecious, with flowers clustered in terminal spikes, with male flowers (3-5) in the lower position and female flowers (1-7) at the top of the inflorescence. The male flowers are yellowish-green with prominent creamy stamens and are carried in ovoid spikes up to 15 cm long; the female flowers, born at the tips of the spikes, have prominent red stigmas (Fig. 2b). A male flower, after opening, releases viable pollen grains for 1-2 days. The stigma is fully receptive a few hours after the flower opens, but it is difficult for pollination to occur shortly after the opening of the flower. The stigma remains receptive after anthesis for a period of 5-10 days, depending on environmental conditions. Castor has a mixed mating system, generating both self-fertilized and cross-fertilized offspring. Under natural conditions, cross-pollination in castor can exceed 80 per cent. The fruit is a thorny, 3-lobed capsule 1.5 to 2.5 cm in diameter, covered with soft spines, each containing one seed (Fig. 2c) (Filho, 2005 and Hussen, 2022).

Because of the vast diversity of this species, India is thought to be one of its centers of origin. The Germplasm Maintenance Unit in the Directorate of Oilseed Research (India) has the largest collection with 3289 accessions of which 253 are exotic collections from 36 countries (Anjani, 2012). A great variation in phenotypic expression is observed due to its cross-pollinated nature. Examples of morphological characters with high variability include stem color, epicuticular wax, plant height, presence of spines on capsules, branching pattern, leaf shape, sex expression, seed color and response to environmental conditions. Wide variation is observed in several morphological traits in the germplasm collections in India, the USSR and elsewhere (Moshkin and Dvoryadkina, 1986; Anjani, 2010 and Weiss, 2000).

The molecular diversity investigations conducted by Bajay *et al.* (2010), Gajera *et al.* (2010) and Zheng *et al.* (2010) using SSR, RAPD, ISSR and SRAP markers showed the existence of large genetic variation in castor germplasm collections. Many morphological and qualitative traits are controlled by one or a few genes. Stem color was reported to show the epistatic interaction of two genes, 'M' (mahogany) and 'G' (green). The combination 'MG' results in a rose coloring, 'Mg' a mahogany, 'mG' a green, and 'mg', a tinged color on the stems (Harland, 1928 and Peat, 1928). Tall plants are dominant over dwarf plants due to a monogenic factor. Characters like bloom, compactness of the spike, presence of spines on the capsule and branching of the stalk appear to be controlled by partial dominance and simply inherited (Rao *et al.,* 2009). The intensity and distribution of bloom on different parts of the plant appear to be controlled by multiple genes (Lavanya and Gopinath, 2008). The inheritance of sexual expression is particularly important in the development of hybrids.

There are three types of pistillate lines that could be used for hybrid production: N, S and NES. In the N type, the occurrence of only female flowers is controlled by a recessive gene (ff). In the S type, the production of only female flowers is controlled by a polygenic complex with dominant and epistatic effects. In the S type, the plant starts as a female, but a reversion to the production of dioecious flowers can occur at any time. In the NES type, the plant has the recessive gene (ff) that allows it to start as female, but when air temperatures exceed 31 °C there is a sexual reversion (Zimmerman, 1958 and Shiffriss, 1960).

Mass selection in castor has been effective for selecting traits with high heritabilities. This technique works best with self-fertilization of selected plants to prevent cross-pollination and controlled selection techniques to reduce environmental variation (Auld *et al.,* 2009). Several tall-type cultivars with late maturation, such as HC-1 to HC-8, EB-16A, S-20, Junagadh-1, Punjab castor-1, EB-31, Rosy and MC-1, were developed in India using this method (Kulkarni and Ramanamurthy, 1977). The development of pistillate lines has allowed breeders to successfully use heterosis (hybrid vigor) in castor. The intensity of heterosis on castor seed yield depends on both the genetic diversity and individual combining ability of the parents (Ramana *et al.,* 2005 and Lavanya *et al.,* 2006). The first commercial castor hybrid, GCH-3, was developed in India. This hybrid had potential seed yields 88 per cent higher than the existing cultivars, medium maturity (140-210 d) and high oil content (466 g kg^{-1}). Since then, a total of 15 hybrids have been released in India, many with resistance to *Fusarium* wilt and high seed yield potential (Lavanya and Solanki, 2010). To create genetic variability in castor, three types of radiation (rays, fast neutrons and thermal neutrons) were used (Kulkarni and Ramanamurthy, 1977). Several other mutagens, like γ rays (40-60 kR), ethidium bromide, and diethyl sulphate (10-50 g kg^{-1}) have also been used in breeding programmes (Lavanya *et al.,* 2006). Baghyalakshmi *et al.* (2020) developed tetraploid (2n=4x=40) castor plants through colchicine treatment.

It has been observed that growth, development and cocoon yield are influenced by the castor genotype and the quality of leaves fed to the worms (Chandrashekhar and Govindan, 2010). In order to evaluate suitable castor genotypes for Eri silkworm rearing, several attempts have been made by different investigators (Sarkar, 1988; Chakravorty and Neog, 2006). Based on the leaf biomass yield of 41 accessions, a local non-bloomy red castor variety (NBR-1) was selected as the most promising variety with a leaf yield of 12 MT/ha/year (Sarmah *et al.,* 2002). Sengupta *et al.* (2008) revealed that NBR-1 and Damalgiri Red are the most nutritionally superior varieties as compared to others and could be exploited for future commercial exploitation in eastern India (Sengupta *et al.,* 2008). Altogether, Acc. 003 (NBR-2) and Acc. 004 (NBR-3) castor genotypes are found to be better in terms of agronomical and yield-attributing traits together with silkworm rearing performance, with a leaf yield of 13 MT/ha/year (Sarmah *et al.,* 2011 and Sarmah & Gogoi, 2011). Selection of castor genotypes based on leaf biomass shows that genotypes 219645, Abaro and 200390 are better than the other castor genotypes for the rearing of Eri silkworm. More over, due to its high fresh leaf yield, genotype 200390 can be considered for future plant breeding work to increase the fresh leaf yield of a given genotype in combination with other agronomic performances (Tulu *et al.,* 2022). Thanga *et al,* (2021), suggest that the castor YTP-1 variety might be employed as a nutritionally promising Eri silkworm host plant (Thanga *et al.,* 2021).

The pest's infestation in castor plants sometimes causes up to 70 per cent leaf loss, which affects Eri silkworm rearing. Therefore, promising accessions of castor were studied by Sarmah and Chakravorty (2005) against major insect pests and evaluated against the castor hairy caterpillar, semilooper, jassids, and capsule borer. The rate of infestation of these insect pests is recorded in different seasons. The accessions, *viz.,* ER-008, ER-009 and ER-001, are found to be resistant to capsule borer and moderately resistant against castor hairy caterpillars, semiloopers, and jassids. Hence, these genotypes can be utilized as parents for future breeding programmes.

Kesseru (*Heteropanax fragrans* Seem)

Kesseru is considered the second-best food plant for Eri silkworms after castor. Due to its perennial and woody nature, it can also withstand pollarding to enhance the availability of foliage (Kumar and Gargi, 1998). Kesseru is being used in various development schemes such as the Augmentation of Eri Food Plant (AEFP), Catalytic Development Programme (CDP), and Cluster Promotion Programme (CPP), to take advantage of its perennial nature. Besides, most of the government farms in Assam and Meghalaya planted kesseru for Eri silkworm rearing (Sarmah *et al.,* 2015). In comparison to castor, kesseru leaves are hard and fibrous, making chewing the leaves difficult. However, the cocoons harvested from the worms fed with kesseru are compact. Hence, it takes more time for degumming during spinning as compared to castor fed ones. Feeding of kesseru foliage during late instar rearing is more suitable. The cocoons become slightly smaller but more compact than castor-fed ones (Sarkar and Borpuzari, 2022).

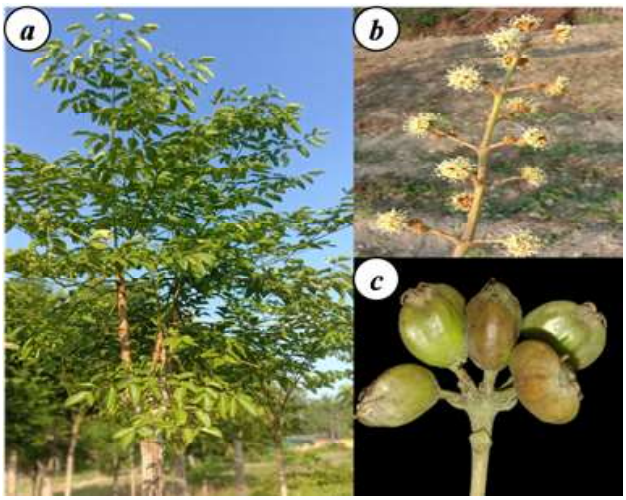

Fig. 3 : Kessaru plant

The *Heteropanax fragrans* Seem is an evergreen plant in the Araliaceae family. The basic chromosome number of Araliaceae is inferred to be x=12 (Yi *et al.,* 2004). It is a popular, fast growing ornamental in Asia. The cultivation of *H. fragrans* is done through seedlings raised in nurseries (Kumar and Gargi, 1998). The tree is found in Bangladesh, China, Cambodia, Hainan, India, Myanmar, Nepal, Vietnam, and Thailand (Brummitt, 2022). It is widely distributed in the northeastern region of India (Assam, Arunachal Pradesh and Meghalaya), both in wild and cultivated conditions. The plant grows up to 30 m tall. The trunk is only branched at the top and the main branches are trichotomous. Leaves are compound, tripinnate, alternate, leaflets opposite, ovate, elliptic or elliptic-lanceolate, 7-8 cm long, glabrous, stipules absent, petiole long (Fig. 3a) (Orwa *et al.,* 2009).

Flowers unisexual or bisexual, actinomorphic, pentamerous, epigynous, yellow, fragrant, male flowers sessile or nearly so in globose heads, bisexual flowers usually at the ends of racemes in umbels; sepals 5, adnate to ovary, limbs short, entire, united; petals 5, free, valvate, triangular, caduceus; stamens 5, filaments inflexed in bud, anther didynaous, versatile; carpels 2, bilocular, style 2, distinct, filiform, ovary inferior, ovule single in each cell (Fig. 3b) (Srivasatva *et al.,* 2005). Anthesis occurs, between 8 and 10 A.M. during December-January (Assam condition). Pollen grains are spherical and on average, measure 35-37 µm in diameter. The pollen grains have 95-98 per cent viability. These can be stored for up to 15 to 22 days at room temperature and 10 °C (Kumar *et al.,* 1993). Fruits are glaucous initially but ultimately turn glabrescent. Fruits are laterally compressed, 2-seeded, 6.5-8.6 mm in diameter and 3.5 mm thick. In dense fleshy albumen, the embryo is minute (Fig. 3c). The average seed set percentage is 78.8 per cent. However, the germination percentage in macroseeds is high compared to microseeds and microseeds take a longer period for germination than macroseeds (Kumar and Gargi, 1998).

There are different genotypes of kesseru in nature. So far, 10 accessions of kesseru, *viz.*, HF-001, HF-002, HF-003, HF-004, HF-005, HF-006, HF-007, HF-008, HF-009 and HF-010, have been identified and maintained in the germplasm bank of the Central Muga Eri Research & Training Institute at Chenijan, Assam (Sarmah *et al.,* 2013). However, HF-008 accession with medium leaves has a potential leaf yield of 27.57 MT/ha/year and HF-005 with smaller leaves has a potential leaf yield of 26.72 MT/

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ha/year. Both varieties are recommended to farmers (CMERTI, 2017).

Cassava/Tapioca (*Manihot* spp.)

Cassava is a secondary food plant of Eri silkworms that is typically used when primary food plants are in short supply. Cassava can be used as the primary food plant of the Eri silkworm during the summer and spring seasons in Assam (Deuri *et al.,* 2016). Further, farmers can also grow castor as a border crop of cassava and rear the chawki (I and II instars) stages of Eri silkworms on castor leaves, then switch over to cassava to enhance the cocoon yield and silk percentage (Sakthivel *et al.,* 2018). In the case of some nutrients, there is no significant difference between castor and tapioca leaves, as well as the cocoon yield and silk percentage, suggesting that tapioca is also a suitable food plant for Eri silkworms (Deuri *et al.,* 2017). The cocoons harvested by cassava-fed worms are white to creamy white in color and elongated to a spindle shape (Das, 2015). The economic analysis revealed that cassava production is more profitable when the sericulture component is included. The north-eastern region of India has ample scope for expansion of cassava cultivation, not only for tuber yield but also for leaf production for Eri silkworm rearing (Saud *et al.,* 2016). Moreover, the incidence of diseases also becomes lower as compared to other host plants of the Eri silkworm (Birari *et al.,* 2019).

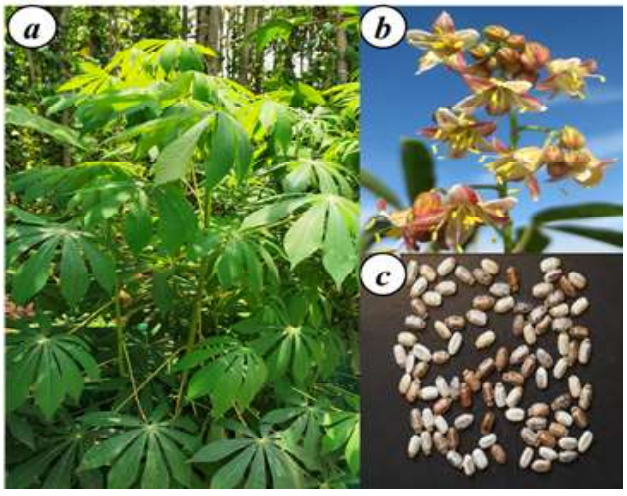

Fig. 4 : Cassava plant

Cassava, *Manihot esculenta* Crantz, does not grow wild. However, about 98 species belonging to the genus *Manihot* (Rogers and Appan, 1973), ranging from subshrubs, shrubs to trees, are known. All cytologically analyzed species of the genus *Manihot* have 2n=36 with small and very similar chromosomes (Carvalho and Guerra, 2002). Jennings (1963), comparing the chromosome numbers of several Euphorbiaceae genera, suggested that the genus *Manihot* could be an allotetraploid derived from the basic number of the family, x=9. Magoon *et al.* (1969) reported the occurrence of pachytene chromosomes in duplicate in cultivars of *M. esculenta,* thereby supporting its putative tetraploid nature and suggesting that its diploid ancestors must have been karyotypically very similar (Umanah and Hartmann, 1973). After analyzing the karyograms of *M. esculenta* and *M. glaziovii*, concluded that they are very similar and that the two satellite chromosome pairs observed in each karyotype indicate the tetraploid level of these species. Cassava does occasionally exhibit meiotic irregularities, possibly due to the almost exclusive use of vegetative propagation to produce the crop, which can result in the accumulation of somatic mutations (Hahn *et al.,* 1990; Olsen and Schaal, 2007 and Sardos *et al.,* 2008). As a result, many cultivars display some sterility, typically due to one of several mechanisms by which the male flowers fail to mature and produce viable pollen (Janick & Byrne, 1984 and Olsen & Schaal, 2007). The genetics of cassava and its relatedness to wild *Manihot* species have been examined using a variety of molecular tools, including isozyme analysis (Cabral *et al.,* 2002); RAPD (random amplified polymorphic DNA) (Nassar, 2000); RFLP (restriction fragment length polymorphism) (Fregene *et al.,* 1997), AFLP (amplified fragment length polymorphism) (Elias *et al.,* 2000) and SSR (simple sequence repeat) and microsatellite markers (Elias *et al.,* 2001; Duputie *et al.,* 2007 and Otti *et al.,* 2011).

Cassava is a perennial, vegetatively propagated shrub, grown throughout the low land tropics. Stem is aerial, erect, glabrous, cylindrical, milky latex containing; marked by prominent scars. It has palmate

(fan-shaped) leaves resembling those of the related castor-oil plant but more deeply divided into five to nine lobes (Rogers and Fleming, 1973). The leaf is simple, with no hairs on the surface and ranges from subsessile to long petiolated, lanceolate, acuminate and are entire with pale green in color. The upper leaf surface is covered with a shiny, waxy epidermis (Cerqueira, 1989). The leaves near the inflorescence are usually reduced in size with three lobes and the leaf closest to the inflorescence is generally simple and unilobed. The leaves have an alternate arrangement and a phyllotaxy of 2/5 (Fig. 4a). The mature leaves are glabrous and are surrounded by two stipules (0.5-1.0 cm long). The length of the petiole ranges from 5 to 40 cm (Alves, 2002).

Cassava is monoecious, bearing separate female and male flowers on the same plant. The flowers are borne together in the inflorescences, with the pistillate flowers beneath the staminate flowers (Fig. 4b). Female flowers have five sepals, which can be red, yellow, or purple and a sticky stigma that secretes nectar on the day the flower opens, attracting insect pollinators (Lebot, 2009). The pistillate flowers are approximately 13x8 mm in size (Janick and Byrne, 1984). The male flowers are half the size of the female flowers, approximately 5 mm, but are more numerous, and each flower has ten stamens, borne in two rings (Janick and Byrne, 1984 and Alves, 2002). The female flowers open for approximately one day and the stigma is receptive throughout that time. Fertilization occurs 8-19 hours after pollination (Andersson and de Vicente, 2010). Individual cassava inflorescences display protogyny, with female flowers opening one to two weeks before the staminate flowers on the same inflorescence. However, because a single plant usually has more than one inflorescence, male and female flowers on the same plant may open at the same time (Alves, 2002). Therefore, while cassava is generally thought to be an outcrossing species, natural self-pollination may also occur, depending on the cultivar (Janick and Byrne, 1984). The pollen grains are large, ranging in size from 90-148 µm in size (Hahn *et al.,* 1990; Alves, 2002; Halsey *et al.,* 2008 and Livia *et al.,* 2012). Typically, pollen viability is lost quickly after shedding; for example, Leyton reported 97 per cent seed set with newly collected pollen, 56 per cent seed set with pollen stored for 24 hours at 25 °C and only 0.9 per cent seed set after 48 hours of storage (Leyton, 1993 and Nassar & Ortiz, 2006). As a result, cassava breeders typically use pollen for crosses within one hour after collection (Halsey *et al.,* 2008 and Andersson & de Vicente, 2010). The fruit of cassava is a tricarpellary capsule and each locule contains one ovule; however, it is common for capsules to contain fewer than three seeds (Kawano, 1980). The fruit reaches maturity two to three months after pollination and the fruit dehisces explosively, although the seed typically falls to the ground near the mother plant (Fig. 4c) (Alves, 2002).

No genetic barriers to crosses between cassava genotypes have been identified, but manual crosses can be difficult to make due to the need for synchronous flowering (Halsey *et al.,* 2008). Experimental interspecific crosses between cassava and its wild relatives have been documented in the literature. Very often, considerable effort, such as embryo rescue, is needed to ensure the success of the interspecific crosses. These crosses result in varying levels of hybrid fertility (Nassar, 2000). Spontaneous tetraploids and triploids have also been observed in the progeny of crosses between cassava and the related species *M. epruinosa* and *M. glaziovii* (Hahn *et al.,* 1990). Some triploids show desirable qualities, such as increased vigor, higher starch accumulation or longer-lasting leaves and some farmers select such triploids for vegetative propagation (Lebot, 2009).

In India, the Central Tuber Crops Research Institute (CTCRI) in Thiruvananthapuram (Kerala) has a cassava collection of 1216 accessions of cassava, comprising indigenous, exotic, landraces and breeding lines. The institute has developed 16 improved varieties and released them into the field. The cassava varieties, *viz.,* H-165, H-226, Sree Athulya, Sree Apoorva and the triploid variety Sree Harsha released for industrial belts of India, played a pivotal role in the growth and development of the starch and

sago industries. The three cassava mosaic disease (CMD) resistant varieties, *viz.,* Sree Reksha, Sree Sakthi and Sree Suvarna, released during 2017-18 with high yield and farmer acceptability, were a break through in cassava research (ICAR-CTCRI, 2021).

The *Manihot esculenta* Crantz (bitter cassava) and *Manihot utilissima* Pohl. (*sweet cassava*) are being exploited for Eri culture in India. In India, it is mostly grown in Kerala, Tamil Nadu, Andhra Pradesh, Karnataka, Nagaland, Meghalaya and Assam. Kerala and Tamil Nadu contribute to the major share of production of cassava. As an additional remuneration to farmers, a portion of cassava leaves is used to produce Eri silk, without affecting the yield or quality of the main produce. The foliage available at the time of removal of weak shoots 6 months after plantations (6 MAP) and during tuber harvest at 10 MAP can be diverted for Ericulture; however, forced leaf plugging up to 20-30 per cent once at 8 MAP is also possible as it does not affect the tuber yield or starch content (Sakthivel, 2012). However, Kawabe (2014) reported that cassava leaves can be trimmed up to 80 per cent without damaging cassava yields.

The selection of location-specific and low HCN content tapioca will make the Ericulture more sustainable and cost effective (Deuri *et al.,* 2017). The order of merit of cassava varieties suitable for Ericulture was recorded by Sakthivel (2016) as MVD1> H226> CO4> CO3> Kunguma Rose > H165> CO2. The highest nutritional values, lower values of anti-nutrient contents, and superior foliage yield in MVD-1 (11.269 MT/ha/year) and H-226 (9.921 MT/ha/year) can be attributed to the superior economic traits, including cocoon yield and silk percentage and are found most suitable for Ericulture compared to the other varieties (Sakthivel & Qadri, 2017 and Sakthivel, 2018). However, the variety H-165 is more suitable under semi-irrigated conditions (Sakthivel, 2018). Further, the efficacy of different tapioca varieties on larval growth and quantitative cocoon characteristics of the Eri silkworm revealed that the larvae reared on the H-97 variety performed better compared to other varieties (Hazarika and Dutta, 2020).

Barkesseru (*Ailanthus excelsa* (Roxb) Seem)

Wild Eri silkworms are frequently found in a natural condition feeding on Ailanthus leaves. Hence, they are often called Ailanthus silk moths. Borkesseru, a potential perennial secondary host plant of the Eri silkworm, can be utilized during the scarcity of the primary host plant without compromising the yield or quality of the cocoon (Sarkar and Borpuzari, 2022). The silkworms can be reared on the leaves of about 2 to 3 year-old plants (Saikia *et al.,* 2008). Saikia (2008) also observed the highest percent of white-colored cocoons from borkesseru fed worms than barpat and castor. The borkesseru leaves found better results in terms of the physical properties of the Eri silk yarn (Borah and Saikia, 2022). As *Ailanthus excelsa* leaves are found abundantly throughout the year, they can be successfully utilized as a substitute food for Eri silkworm rearing during the scarcity of castor leaves (Khanikor *et al.,* 1997; Deori and Khanikor, 2015). The CEMRTI (2021) identified five accessions of borkesseru based on leaf morphological characteristics: AE-001, AE-002, AE-003, AE-004 and AE-005.

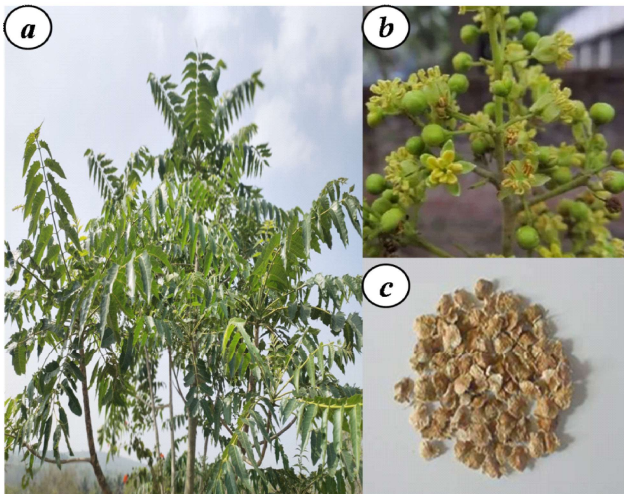

Fig. 5 : Borkessaru plant

The *Ailanthus excelsa* Roxb. is a deciduous tree belonging to the family Simaroubaceae; commonly, it is known as the 'Tree of Heaven'. In India, it is distributed in the central, western and southern parts of the sub-continent (Kumar *et al.,* 2010). It is a fast-growing tree species for dry areas and suitable

for industrial forestry due to its adaptation to low moisture and high temperature conditions (Seth *et al.,* 1962 and Bhimaya *et al.,* 1963). The tree can be raised from both seeds and stumps. Its quick growth and absolute immunity to grazing give the species first choice among the soft woods (Anonymous, 1956). The leaves are rated as highly palatable and nutritious fodder for sheep and goats and an average tree yields about 500-700 kg of green leaves twice a year (Singh and Patnayak, 1977). This tree is widely cultivated in Tamil Nadu farmlands and is a favorite for matchwood, plywood and the packing case industry (Rajasugunasekar, 2014). The tree attains height of 18-25 m tall; trunk straight, 60-80 cm in diameter; bark light grey and smooth, becoming grey-brown and rough on large trees, aromatic, slightly bitter. Leaves alternate, pinnately compound, large, 30-60 cm or more in length; leaflets 8-14 or more pairs, long stalked, ovate or broadly lance shaped from very unequal base, 6-10 cm long, 3-5 cm wide, often curved, long pointed, hairy gland; edges coarsely toothed and often lobed (Fig. 5a) (Orwa *et al.,* 2000).

Flowers are numerous, mostly male and female on different trees, short stalked and greenish-yellow; the calyx is 5 lobed; the petals are 5 narrow and spread 6 mm across; stamens are 10 and on other flowers, there are 2-5 separate pistils, each with an elliptical ovary, 1 ovule, and slender style (Fig. 5b). The flowers appear in large, open clusters among the leaves towards the end of the cold season. Male, female and bisexual flowers are intermingled on the same tree (Orwa *et al.,* 2009). The floral buds took 9-13 days to come into bloom. Between 08:00 and 09:00 h, more than 80 per cent of the floral buds opened. The number of days required from panicle initiation to fruit maturity ranged from 132-140. Fruit set under open-pollination is higher as compared to the fruit set in self-pollinated trees and a highly significant difference in the growth characteristics of self-versus open pollinated progenies formed strong evidence for the xenogamous behavior of borkesseru (Daneva *et al.,* 2018). The fruits ripen just before the onset of the monsoon. The seeds are very light and are dispersed far and wide by the wind. The fruit has a flat, membranous samara and is dispersed by wind (Fig. 5c). It has been reported as a dioecious or polygamo-dioecious species with male, female and bisexual flowers (Nooteboom, 1962 and Jat *et al.,* 2011). Female plants have slightly higher genetic diversity than males in all *A. excelsa* populations under arid conditions (Bano *et al.,* 2020).

The diploid chromosome number in *Ailanthus excelsa* was reported as 2n=62 (Darlington and Wylie, 1956), 2n=82 (Ghosh, 1970; Kumar and Subramaniam (1987) and 2n=86 (Bedi, 1991). Rajasugunasekar *et al*. (2012) revealed the genetic diversity in *A. excelsa* genotypes from different regions of India. High gene flow and low genetic differentiation in *A. excelsa* indicate poor population fragmentation despite long geographic distances (Bano *et al.,* 2020). The breeding programme in *A. excelsa* was initiated by the Institute of Forest Genetics and Tree Breeding (Coimbatore, India) in 2007 with an assemblage of germplasm from different agroclimatic zones, followed by multi-environment trials to identify phenotypes suitable for industrial application (Dasgupta *et al.,* 2021). Ample genetic variation was observed by Daneva *et al.* (2018) in twenty-one plus trees of *A. excelsa* for field emergence, seedling height, shoot length, root length, basal diameter and number of branches. Among the 30 progenies evaluated by Kanna *et al*. (2020) under field conditions, three progenies, *viz.,* FCRI AE-6, FCRI AE-16 and FCRI AE-26, consistently expressed superiority for all four biometric traits *viz.,* plant height, basal diameter, branch index and volume index at four growth periods and these progenies could be exploited for current utilization and future tree improvement programmes. Among the growth attributes, the volume index contributed the highest percentage towards genetic divergence (Kanna *et al.,* 2019). The number of branches showed maximum PCV and GCV, followed by volume index, plant height, basal diameter, chlorophyll a/b ratio and total chlorophyll content, which have low phenotypic coefficient of variation and genotypic coefficient of variation. Plant height, basal diameter, volume index, chlorophyll a, chlorophyll b, chlorophyll a/b ratio and total chlorophyll content have high heritability coupled with low, moderate and high

genetic advance as percentages of the mean (Kanna *et al.,* 2019). Tomar *et al.* (2019) observed that female trees are superior to male trees in all the parameters except the length of the primary root. The greatest difference was seen in the fresh leaf (fodder) weight and number of branches, where female plants had 71 and 69 per cent higher biomass, respectively.

Barpat (*Ailanthus grandis* Prain)

Barpat plants have been identified as potential substitutes for the major host plant (castor) based on their nutritional quality and bioassay performance. Adoption of the barpat tree for the rearing of the Eri silkworm among Eri rearers will help in the commercialization of Ericulture and will overcome the problem of the non-availability of sufficient leaves throughout the year, besides mitigating deforestation and the effects of climate change (Senthilkumar *et al.,* 2006 and Ahmed e*t al.,* 2015). Barpat has been identified as a potential perennial food plant for Eri silkworms and has been recommended for field use (CSB, 2020). Based on a leaf morphological study, four accessions of *Ailanthus grandis*, *i.e.*, AG-001, AG-002, AG-003 and AG-004, were identified. It has a recoded leaf yield of 32 MT/ha/year as compared to Kesseru's leaf yield of 25 MT/ha/year (CMERTI, 2017). Barpat is a lofty tree, growing in India, Vietnam, Thailand and China. It is widely distributed in the foothills of the Himalayan range of the north-eastern region, more specifically in Arunachal Pradesh and Nagaland states (Basak, 1980 and Hung *et al.,* 1995).

Fig. 6 : Barpat plant

The wood too can be put to several uses, including box planking, matchmaking, and newsprint-grade pulp (Guhathakurta and Ghosh, 1972).

The *Ailanthus grandis* Prain is aneuploid in nature at the diploid level (Singhal *et al.,* 1985) with 2n=62 and 2n=64 chromosomes (Mehra and Khosla, 1969; Gill *et al.,* 1979; Kumar and Subramaniam, 1987) and has 99 percent of pollen fertility (Singhal *et al.,* 1985). *Ailanthus grandis* Prain belongs to the family Simaroubaceae, and it is a tall tree of nearly 120-180 ft (Srivastav *et al.,* 2005). It has several desirable external form and behavior characteristics, such as a faster rate of growth, a straight cylindrical bole without unwanted flares at the base and not too great a taper at the top, a restricted crown enabling a greater economy of aerial space, a habit of natural pruning, apical dominance of shoots, and a thin back, which have made it eminently suitable for maximizing production in a short period of time (Guhathakurta and Ghosh, 1972). The leaves are compound, alternate, leaflets entire, 5-8 pairs, 15-20 cm long (Srivastav *et al.,* 2005). Flowering occurs in September, and fruits are ripe from February to March (Patidar *et al.,* 2022). The fruit is a winged samara, with ripe carpels 10-15 cm long and a rounded and obtuse apex (Srivastav *et al.,* 2005). Seeds are light brown in color with a very thin membranous testa and oily cotyledons (Bisht *et al.,* 1980). Although, it is erratic in flowering and fruiting habits and output, No two consecutive seed years are good, and there is different fruiting from tree to tree even within the same plantation (Patidar *et al.,* 2022). It has a long dormant period that ends with the arrival of the monsoon and a low viability (Guhathakurta and Ghosh, 1972).

Barpat is commonly propagated through seeds collected from forests or cultivated plantations. There are some limitations in its mass multiplication for distribution among farmers. Although its propagation

TABLE 1
Comparative account of leaf yield and quality of eri host plants

Parameters	Castor	Kesseru	Tapioca	Borkesseru	Barpat
Leaf yield	12-13MT/ ha/year	26 -27MT/ ha/year	9 -11MT/ ha/year	500-700 kg/ plat/ twice a year	32.00 MT/ ha/yr
Leaf moisture content (%)	72.75- 81.52	85.59	74.8-81.00	81.57	-
Carbohydrate (%)	22.85	11.68	13.02	13.63	-
Crude fiber (%)	12.35	15.68	17.85	14.41	-
Free amino acid (mg/100 g)	1.29	-	0.27	-	-
Lipid (%)	14.89	2.92	1.0-2.00	3.25	4.90
Phenol (mg/100g)	21.27	-	18. 2- 40.14	-	-
Sugar (%)	6.42	5.30	5.89	5.73	-
Ash content (%)	10.00	-	4.6-6.40	-	9.50

through seeds is robust, it is erratic in its flowering and fruiting habits. The non-synchronous, erratic seed behavior of the barpat is the biggest issue in propagating it through seed. Another issue is the nature of cross-pollination, which limits the ability to provide true-to-type seedling material, as seed material from wildly collected seeds has a high chance of mixing the important cultural trait of barpat. However, air layering has recently been investigated at CMERTI, Lahdoigarh, Assam, but since it produces a few shoots from axillary buds, mass multiplication is not possible. In this case, hormonal treatment to initiate multiple shoots from axillary buds on the main shoot, which can be used for stem cutting or air layering, needs to be attempted. Furthermore, micropropagation via tissue culture may be used to produce barpat seedlings or saplings on a commercial scale. Thus, horizontal expansion of the Ericulture is needed at the highest priority, and barpat can contribute to it significantly if the propagation of the true-to-type seedling or sapling can be achieved at a commercial scale. Tissue culture can be the best option in this direction, and protocol optimization needs to be a top priority (Patidar *et al.,* 2022).

Payam (*Evodia flaxinifolia* Hook F.)

The payam tree, which is endemic to northeast India, is emerging as a potential food plant for Eri silkworms and as an alternative food source to the castor plant (Yumnam, 2003). The important characteristics like shell weight, silk ratio, empty cocoon weight, yarn weight, yarn realization, degumming loss and waste with payam-fed cocoons are comparable with those of castor and kesseru. Therefore, payam is an alternative food plant, particularly during the off-season for sustainable rearing of the Eri silkworm in Nagaland (Kakati and Merenjungla, 2018). It also found that payam leaves are also suitable for rearing cross-breeds of Eri silkworms (Dulur *et al.,* 2016). The community plantation of payam for Eri culture is popularized by the Basin Development Unit (BDU) under the Catalytic Development Programme (CDP) scheme of the Sericulture Department in Meghalaya (MBDA, 2015). The payam tree is grown in the hilly areas of Nepal, Meghalaya, Nagaland, Sikkim and Assam (Dulur *et al.,* 2013). The plant is cultivated as fodder. Wood is soft and white and is used for posts and for making tea chests, ceiling boards, partitions, and match splints (Kanjilal, 2005).

The palyam is a member of the Rutaceae family and has a diploid chromosome number of 2n=72 (Darlington and Wylie, 1956). It is a moderate sized, monoecious, much branched, densely leafy, strongly aromatic evergreen tree; stem aerial, erect, branchlets thick, stout, terete; leaf compound, opposite, imparipinnate, glabrous, petiole cylindric and pilose.

leaflets 3-6 pairs, leaf 20-30 cm long spreading, bright green, leaflets 10-20 cm long, shortly petioled, oblong or oblong-lanceolate, acuminate, straight or falcate, entire or crenulate, base rounded often oblique, nerves spreading, slender, terminal leaflets usually long petioled (Srivstava *et al.,* 2005).

Inflorescence axillary or terminal cymes, peduncles short, compressed, finely pubescent; flowers unisexual, actionomorphic, hypogynous with minute bracts, pedicel short, 4-5 merous, greenish white, male flowers approximately 1.2 cm across; sepals 4-5, small, free, obtuse, imbricate; petals 4-5, pubescent within, much longer, linear, imbricte, sessile, free; stamens 4-5 in male flowers only, filaments longer than petals, hairy, anther broad, inserted at the base of the disc; carpels 4, ovary deeply 4- lobed, glabrous, ovule 2 in each cell, stigma 4-lobed, capitates, style short, 4 rudimentry ovaries present in male flowers; fruit red, 1.3 cm across, carpels not separating upto base, very coriaceous; seed broadly elliptic, slightly compressed; flowering in May (Srivstava *et al.,* 2005).

Improvement of Eri host plant varieties for suitable Eri rearing is a prime step for boosting the Eri culture industry. In India, there are over a thousand genotypes or accessions of castor and cassava. However, only a few accessions are evaluated for Ericulture, so the rest of the accessions need to be screened for rearing suitability as well as foliage quality and quantity parameters. Triploid genotypes have many advantages (fast-growing nature, higher leaf yield with better nutrients) and if applied in castor, they can be developed through crossing tetraploid with diploid parent lines by using hybrid seed production techniques. Moreover, no chromosome number information is available in the kessaru plant, which needs to be confirmed. Generally, Eri host plants are cross-pollinated and heterozygous by nature, which limits true-to-type progenies and reduces their economic traits as well. Thus, improvement of host plants (kessaru, borkessaru, barpat and payam) that are more amenable to vegetative propagation is required. Furthermore, Eri rearing can be done for 5-6 crops per year; therefore, perennial host plant varieties with dwarfing types, adaptability to adverse conditions and the ability to produce higher quantities and better quality foliage suitable for Eri culture need to be developed. Moreover, the improvement of the tertiary food plant, jatropa, for suitable Eri rearing gives it more advantages than all host plants due to their characteristics, which meet the aforesaid ideal Eri host plant nature.

References

Ahmed, S. A., Sarkar, C. R., Sarmah, M. C., Ahmed, M. and Singh, N. I., 2015, Rearing performance and reproductive biology of Eri silkworm, *Samia ricini* (Donovan) feeding on *Ailanthus* species and other promising food plants. *Adv. Biol. Res.,* **9** : 07 - 14.

Alves, A. A. C., 2002, Cassava botany and physiology, chapter 5, in : Hillocks, R. J., Thresh, J. M. and Bellotti, A. C. (Eds.), Cassava: Biology, production and utilization, CABI, Wallingford, United Kingdom, pp. : 67 - 89.

Andersson, M. S. and De Vicente, M. C., 2010, Cassava, Manioc, Yuca, Chapter 6, In: Andersson M. S. and de Vicente, M. C. (Eds.), Gene flow between crops and their wild relatives, Johns Hopkins University Press, Baltimore, Maryland, pp. : 125 - 146.

Anjani, K., 2010, Extra-early maturing germplasm for utilization in castor improvement. *Ind. Crops Prod.,* **31** : 139 - 144.

Anjani, K., 2012, Castor genetic resources: A primary gene pool for exploitation. *Ind. Crops Prod.,* **35** : 1 - 14.

Anonymous, 1956, The wealth of India: Raw materials, council of industrial and scientific research, New Delhi, pp. : 116 - 118.

Anonymous., 2021, Statistical Handbook of Assam-2021. Chapter-11, Sericulture, Directorate of Economics and Statistics, Govt. of Assam, pp. : 197 - 202.

Armuganathan, K. and Earle, E. D., 1991, Nuclear DNA content of some important plant species. *Pl. Mol. Biol. Rep*., **9** : 208 - 218.

Arora, G. S. and Gupta, L. J., 1979, Taxonomic studies on some of the Indian non-mulberry silk moths

(Lepidoptera : Saturniidae). *Mem. Zool. Survey India,* **16** : 1 - 63.

Auld, D. L., Zanotto, M. D., McKeon, T. and Morris, J. B., 2009, Castor, In : Vollmann J. and Rajcan I. (Eds.), Oil Crops-Handbook of Plant Breeding. Springer, New York. pp. : 316 - 332.

Baghyalakshmi, K., Shaik, M., Mohanrao, M., Shaw, R., Lavanya, C., Manjunatha, T. and Senthilvel, S., 2020, Development and characterization of tetraploid castor plants. *Plant Genet. Resour.,* **18** : 98 - 104.

Bajay, M. M., 2010, Development of microsatellite markers and characterization of germplasm of castor (*Ricinus communis* L.). Dissertation, Universidade de Sao Paulo-USP, Brazil.

Bano, S., Ansari, S., Choudhary, M. and Tomar, U. K., 2020, Gender-based genetic variability of *Ailanthus excelsa* Roxb, populations using, RAPD, ISSR and SCoT Markers. *Curr. J. Appl. Sci. Technol.,* **39** : 75 - 83.

Basak R. K., 1980, Fascicles of Flora of India, Botanical Survey of India, Botanic Garden, Fascicle 4, pp.: 1-7.

Bedi, Y. S., 1991, Chromosomal conspectus and evolutionary status of Indian commercial timbers (hardwoods). *Cytologia,* **56** : 665 - 672.

Bhimaya, C. P., Kaul, R. N. and Ganguky, B. N., 1964, Species suitable for afforestation of different arid habitats of Rajasthan. *J. Arid Land,* **2** : 162 - 168.

Bindroo, B. B., Singh Tiken, N., Sahu, A. K. and Chakravorty, R., 2007, Eri silkworm host plants. *Indian Silk,* pp. : 13 - 16.

Birari, V. V., Siddhapara, M. R. and Desai, A. V., 2019, Rearing performance of Eri silkworm, *Samia ricini* (Donovan) on different host plants. *J. Farm. Sci.,* **32** : 443 - 446.

Bisht, N. S., Awat, S. P. A. and Singh, U. V., 1980, Nursery techniques of local tree species. State Forest Research Institute (SFRI) Information Bulletin No. 9. pp. : 6.

Borah, R. R. and Saikia, M., 2022, Effect of *Ailanthus* species and seasons on yarn parameters of Eri silk. *Environ. Conserv.,* **23** : 15 - 21.

Brahma, D., Swargiary, A. and Dutta, K., 2015, A comparative study on morphology and rearing performance of *Samia ricini* and *Samia canningi* crossbreed with reference to different food plants. *J. Entomol. Zool. Stud.,* **3** : 12 - 19.

Brummitt, R. K., 2022, World geographical scheme for recording plant distribution (Eds. 2), International Working Group on Taxonomic Databases for Plant Sciences (TDWG) by the Hunt Institute for Botanical Documentation Carnegie Mellon University, Pittsburgh. Retrieved 10 September 2022.

Cabral, B. L. R., Souza, J. A. B., Ando, A., Veasey, E. A. and Cardoso, E. R., 2002, Isoenzymatic variability of cassava accessions from different regions in Brazil. *Sci. Agric.,* **59** : 521 - 527.

Carvalho, R. D. and Guerra, M., 2002, Cytogenetics of *Manihot esculenta* Crantz (cassava) and eight related species. *Hereditas,* **136** : 159 - 168.

Chakravorty, R. and Neog, K., 2006, Food plants of eri silkworm, *Samia ricini* (Donovan), their rearing performance and prospects for exploitation. In : Plants, Chakravorty, R., Rahman, S.A.S., Neog, K. (Eds.), Proceeding on National Workshop on Eri Food. Central Muga Eri Research and Training Institute, Jorhat, India, pp. : 1 - 7.

Chan, A. P., Crabtree, J., Zhao, Q., 2010, Draft genome sequence of the oilseed species *Ricinus communis*. *Nat. Biotech.,* **28** : 951 - 956.

Chandrashekhar, S. and Govindan, R., 2010, Studies on the performance of castor genotypes on rearing cocoon of Eri-silkworm. *Int. J. Plant Prot.,* **3** : 219 - 224.

Chowdhury, S. N., 1982, Eri silk industry directorate of sericulture weaving, Government of Assam (India), pp. : 178.

Cmerti, 2017, Technology descriptors in muga and Eri culture. pp. : 21.

Csb, 2017, Annual report, Central Silk Board. 2016-17, pp. : 09.

Csb, 2022, Seri cultural statistics in India - A glance, Central Silk Board, Accessed July 10, 2022 at https://

www.cabdirect.org/cabdirect/abstract /19780559488 https://csb.gov.in/wp-content/uploads/2022/07/Raw-Silk-Production.pdf.

CSB, 2020, Functioning of Central Silk Board and note on Sericulture, Central Silk Board, pp. : 03.

DANEVA, V., DHILLON, R. S. AND JOHAR, V., 2018, Plus tree selection and progeny testing of superior candidate plus trees (CPTs) of *Ailanthus excelsa*. *J. pharmacogn. phytochem.,* **7** : 543 - 545.

DARLINGTON, C. D. AND WYLIE, A. P., 1956, Chromosome atlas of flowering plants. Chromosome atlas of flowering plants. George Allen and Unwin Ltd., London, UK.

DAS, D., 2015, Rearing of Eri silkworms (*Philosamia ricini* Hutt.) on tapioca (*Manihot utilisima*) during autumn season in Assam. *Indian J. Appl. Res.,* **5** : 527 - 528.

DAS, S. K., SAHU, B. K. AND SINGH, D., 2020, Host plant diversity of non-mulberry silkworms : A review. *J. pharmacogn. phytochem.,* **9** : 109 - 113.

DASGUPTA, M. G., PARVEEN, A., RAJASUGUNASEKAR, D. AND ULAGANATHAN, K., 2021, Wood transcriptome analysis and expression variation of lignin biosynthetic pathway transcripts in *Ailanthus excelsa* Roxb., a multi-purpose tropical tree species. *J. Biosci.,* **46** : 105.

DEBARAJ, Y., SINGH, B. K., DAS, P. K. AND SURYANARAYANA, N., 2003, Payam : An evergreen host plant of Eri silkworm. *Indian Silk,* **42** : 5 - 6.

DEORI, G. AND KHANIKOR, D. P., 2015, Rearing performance of Eri silkworm (*Samia ricini* Boisd.) on *Ailanthus excelsa* and *Ailanthus grandis*. *J. Exp. Zool. India,* **18** : 839 - 841.

DEURI, J., BARUA, P. K. AND SARMAH, M. C., 2016, Effect of food plants on rearing performance and cocoon quality of Eri silkworm (*Samia ricini* Donovan). *World J. Agric. Sci.,* **12** : 431 - 436.

DEURI, J., BARUA, P. K., SARMAH, M. C. AND AHMED, S. A., 2017, Biochemical attributes of castor and tapioca leaves, the promising food plants of Eri silkworm (*Samia ricini* Donovan). *Int. J. Ecol. Ecosolution.,* **4** : 1 - 4.

DULUR, B., DUTTA, K. AND DEORI, S., 2013, Probability of new host plant *Evodia fraxinifolia* in Kokrajhar district, 1st Bodoland National Seminar cum Workshop on Sericulture Industry and its role in the Socio-Economic Upliftment in Rural Society, Bodoland University, Kokrajhar Vol. : 1.

DUPUTIE, A., DAVID, P., DEBAIN, C. AND MCKEY, D., 2007, Natural hybridization between a clonally propagated crop, cassava (*Manihot esculenta* Crantz) and a wild relative in French Guiana. *Mol. Ecol.,* **16** : 3025 - 38.

ELIAS, M., PENET, L., VINDRY, P., 2001, Unmanaged sexual reproduction and the dynamics of genetic diversity of a vegetatively propagated crop plant, cassava (*Manihot esculenta* Crantz), in a traditional farming system. *Mol. Ecol.*. **10** : 1895 - 1907.

ELIAS, M., PANAUD, O. AND ROBERT, T., 2000, Assessment of genetic variability in a traditional cassava (*Manihot esculenta* Crantz) farming system, using AFLP markers. *Heredity,***85** : 219 - 230.

FREGENE, M., ANGEL, F., GOMEZ, R., 1997, A molecular genetic map of cassava (*Manihot esculenta* Crantz). *Theor. Appl. Genet.,* **95** : 431 - 441.

GAJERA, B. B., KUMAR, N., SINGH, A. S. AND PUNVAR B. S., 2010, Assessment of genetic diversity in castor (*Ricinus communis* L.) using RAPD and ISSR markers. *Ind. Crops Prod.,* **32** : 491 - 498.

GHOSH, R. B., 1970, Karyomorphological studies of somatic chromosomes in *Ailanthus excelsa* Roxb. - An ornamental and a road-side plant. *Broteria,* **39** : 3 - 8.

GILL, B. S., BIR, S. S. AND SINGHAL, V. K., 1979, In IOPB chromosome number reports LXV. *Taxon,* **28** : 630.

GOVAERTS, R., FRODIN, D. G. AND RADCLIFFE-SMITH A., 2000, World checklist and bibliography of Euphorbiaceae (with Pandaceae). Redwood Books Limited, Trowbridge, Wiltshire.

GUHATHAKURTA, P. AND GHOSH, R. C., 1972, *Ailanthus grandis Prain - Its prospect in forestry. Indian For.,* **98** : 261 - 270.

HAGERUP, C., 1932, Uber ployploidie in beziehung zu klima, okologie und phylogenie. *Hereditas,* **16** : 19 - 40.

HAHN, S. K., BAI, K. V. AND ASIEDU, R., 1990, Tetraploids, triploids and 2n pollen from diploid interspecific crosses with cassava. *Theor. Appl. Genet.,* **79** : 433 - 439.

HALSEY, M., KENNETH, O., NIGEL, T. AND PAUL, C., 2008, Reproductive biology of cassava (*Manihot esculenta* Crantz) and isolation of experimental field trials. *Crop Sci.,* **48**.

HARLAND, S. C., 1928, The genetics of *Riciuns communis* L. *Bibliotheca Genetica,* **4** : 171 - 178.

HAZARIKA, M. AND DUTTA, L. C., 2020, Efficacy of different tapioca varieties on larval growth and quantitative cocoon characters of Eri silkworm, *Samia ricini* Boisd. *J. Exp. Zool. India,* **23** : 1707 - 1709.

HAZARIKA, M., DUTTA, L. C., BHATTACHARJEE, J. AND PATGIRI, P., 2015, Nutritional efficiency of Eri silkworm, *Samia ricini* Boisd. reared on four different varieties of tapioca. *J. Exp. Zool. India,* **18** : 831 - 833.

HUNG, T., STUPPNER, H., ELLMERER-MULLER, E. P., SCHOLZ, D., EIGNER, D. AND MANANDHAR, M. P., 1995, Steroids and terpenoids from the gum resin of *Ailanthus grandis*. *Phytochemistry,* **39** : 1403 - 1409.

HUSSEN, K. W., 2022, Review on reproductive biology of caster bean (*Ricinus communis* L.). *J. Ecol. Nat. Resour.,* **6** : 000268.

ICAR-CTCRI, 2021, Annual Report 2021, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India, pp. : 4.

JACOB, K. M., 1956, The pachytene chromosomes of the castor oil plant. *Cytologia,* **21** : 76 - 80.

JACOB, K. M. AND ATSMON, D., 1965, Sex inheritance in *Ricinus communis* L. : Evidence for a genetic change during the ontogeny of female sex reversals. *Genetica,* **36** : 253 - 259.

JANICK, J. AND BYRNE, D., 1984, Breeding cassava, Chapter 3, in: Plant Breeding Reviews, **2** : 73 - 133.

JAT, H. S., SINGH, R. K. AND MANN, J. S., 2011, Ardu (*Ailanthus* sp.) in arid ecosystem : A compatible species for combating with drought and securing livelihood security of resource poor people. *Indian J. Tradit. Knowl.,* **10** : 102 - 113.

JENNINGS, D. L., 1963, Variation in pollen and ovule fertility in varieties of cassava and the effect of interspecific crossing on fertility. *Euphytica,* **12** : 69 - 76.

KAKATI, L. N. AND MERENJUNGLA, 2018, Production parameters and yarn realization in Eri silkworm *Samia ricini* as influenced by alternative host plants. *Indian J. Entomol.,* **80** : 114 - 123.

KANJILAL, U. N., 2005, Flora of Assam : Vol. I : 196. Omsons Publications, New Delhi.

KANNA, S. U., KRISHNAKUMAR, N. AND JAILANI, K. M. M. A. K., 2019, Growth performance of *Ailanthus excelsa* through progeny test. *J. Pharm. Innov.,* **8** : 204 - 210.

KANNA, S. U., KRISHNAKUMAR, N. AND JAILANI, K. M. M. A. K., 2019, Variability, heritability and genetic advance of *Ailanthus excelsa*. *Int. J. Curr. Microbiol. App. Sci.,* **8** : 1508 - 1517.

KANNA, S. U., KRISHNAKUMAR, N. AND JAILANI, K. M. M. A. K., 2019, Genetic divergence studies in *Ailanthus excelsa* using D2 analysis. *Int. J. Environ. Clim.,* **9** : 416 - 424.

KAUSHIK, N., DESWAL, R. P. S., JAKHAR, V. AND ARYA, S., 2019, Variation in seed and seedling traits of Mahaneem (*Ailanthus excelsa* Roxb.). *Int. J. Genet.,* **11** : 674 - 640.

KAVANE, R., 2014, *Carica papaya* - A potential host of *Philosamia ricini* Eri silkworm under Western Maharashtra condition. *Indian J. Appl. Res.,* **4** : 472 - 474.

KAWABE, K., 2014, Changes in cassava yields with trimmed leaves for Eri-culture in Kampong Cham Province, Cambodia. *Int. J. Environ. Rural Dev.,* **5** : 183 - 187.

KAWANO, K., 1980, Cassava, Chapter 13, in: Fehr W. R. and Hadley H. H. (Eds.), Hybridization of crop plants, American Society of Agronomy/Crop Science Society of America, Madison, Wisconsin, pp.: 225-233.

KHANIKOR, D. R., DUTTA, S. K. AND KHOUND, J. N., 1997, Exploitation of borkesseru (*Ailanthus excelsa* Roxb.) leaves as a substitute of castor leaves for rearing Eri silkworm (*Philosamia ricini* Hutt.) (Lepidoptera : Satumiidae). *New Agriculturist*, **8** : 7 - 12.

KULKARNI, L. G. AND RAMANAMURTHY, G. V., 1977, Castor. ICAR, New Delhi.

KUMAR, D., BHAT, Z. A., SINGH, P., SHAH, M. Y. AND BHUJBAL, S. S., 2010, *Ailanthus excelsa* Roxb. is really a plant of heaven. *Int. J. Pharmacol.,* **6** : 535 - 550.

KUMAR, R. AND GARGI, 1998, Studies on seed longevity and germination in *Heteropanax fragrans*. *Sericologia,* **38** : 527 - 532.

KUMAR, R., GARGI AND PRASAD, D. N., 1993, Studies on *in vitro* pollen germination and pollen tube elongation in *Heteropanax fragrans* L. (Araliaceae). *Indian J. Seric.,* **32** : 87 - 90.

KUMAR, V. AND SUBRAMANIAM, B., 1987, Chromosome atlas of flowering plants of the Indian Subcontinent, Botanical Survey of India.

KURITA, M., 1946, Secondary association of chromosomes in castor oil plant. *Jpn. J. Genet.,* **21** : 63.

LAVANYA, C. AND GOPINATH, V., 2008, Study on inheritance of morphological characters and sex expression in pistillate lines of castor. *Indian J. Genet. Plant Breed.,* **68** : 275 - 282.

LAVANYA, C. AND SOLANKI, S. S., 2010, Crop improvement of castor, The challenges ahead. In: Hegde D. M. (Eds.), Research and development in castor: Present status and future strategies, Indian Soc. of Oilseeds Res., Hyderabad.

LAVANYA, C., RAMANARAO, P. V. AND GOPINATH, V. V., 2006, Studies on combining ability and heterosis in castor hybrids. *J. Oilseeds Res.,* **23** : 174 - 177.

LAVHALE, M. S. AND MISHRA, S. H., 2007, Nutritional and therapeutic potential of *Ailanthus excelsa* : A review. *Pharmacognosy Rev.,* **1** : 1 05 - 113.

LEBOT, V., 2009, Tropical root and tuber cropsn: Cassava, sweet potato, yams and aroids, crop production science in horticulture series, Volume 17, CABI, Wallingford, United Kingdom.

LEITCH, I. J., JOHNSTON, E., PELLICER, J., HIDALGO, O. AND BENNETT, M. D., 2019, Plant DNA C-values database (release 7.1, Apr 2019) https://cvalues.science.kew.org/

LEYTON, M., 1993, Cryopreservation of pollen from Yucca, Diss. Valley University, Cali, Colombia.

LIVIA, D., TALIANE, S., MONICA, R., ALFREDO, A., FRANCISCO, S. AND FERNANDA, V., 2012, Viability, production and morphology of pollen grains for different species in the genus *Manihot* (Euphorbiaceae). *Acta Bot. Bras.,* **26** : 350 - 35.

MAGOON, M. L., KRISHNAN, R. AND VIJAYABAI, K., 1969, Morphology of pachytene chromosomes and meiosis in *Manihot esculenta* Crantz. *Cytologia,* **34** : 612 - 618.

MBDA, 2015, Meghalaya basin development authority (MBDA), Government of Meghalaya, India. https:// mbda.gov.in/community-plantation-kessaru-payam-trees-ri-bhoi. Accesed on 31/12/2022.

MOSHKIN, V. A. AND DVORYADKINA, A. G., 1986, Cytology and genetics of qualitative characters. In: Moshkin V.A. (Eds.) Castor. New Delhi: Amerind, pp. : 93 - 102.

NAIK, M. C. AND MURTHY, C., 2013, Evaluation of new host plant species for Ericulture. *Internat. J. Plant Protec.,* **6** : 444 - 448.

NASSAR, N. M. A., 2000, Cytogenetics and evolution of cassava (*Manihot esculenta* Crantz). *Genet. Mol. Biol.,* **23** : 1003 - 1014.

NASSAR, N. M. A. AND ORTIZ, R., 2006, Cassava improvement : Challenges and impacts. *J. Agric. Sci.,* **145** : 163 - 171.

NOOTEBOOM, H. P., 1962, Simaroubaceae. Flora Malasiana Series 1st. **16** : 193 - 226.

OLSEN, K. AND SCHAAL, B. A., 2007, Insights on the evolution of a vegetatively propagated crop species. *Mol. Ecol.,* **16** : 2838 - 2840.

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R. and Anthony, S., 2009, Agroforestry Database : A tree reference and selection guide version 4.0, 2009. (http: //www. worldagroforestry. org/ sites/ treedbs/ treedatabases.asp).

Otti, G., Fakoya, A., Andrew, I. and Gedil, M., 2011, Development of genomic tools for verification of hybrids and selfed progenies in cassava (*Manihot esculenta*). *Afr. J. Biotechnol.,* **10** : 17400 - 17408.

Paris, H. S., Shifriss, O. and Jelenkovic, G., 1978, Idiogram of *Ricinus communis*. *J. Heredity,* **69** : 191 - 196.

Patidar, O. P., Jigyasu, D. K., Shabnam, A. A. and Kumar, A., 2022, Utilization of barpat (*Ailanthus grandis*) for up-scaling of Ericulture: Scope, limitations and strategies. *Plant Arch.,* **22** : 22 - 25.

Patil, R. R., Kusugal, S. and Ankad, G., 2009, Performance of Eri silkworm, *Samia cynthia ricini* Boisd. on few food plants. *Karnataka J. Agric. Sci.,* **22** : 220 - 221.

Patil, R. R., Ankad, G. and Sunita, K., 2006, *Jatropha curcas* : An alternate host plant of Eri silkworm?. *Indian Silk,* **45** : 17.

Peat, J. E., 1928, Genetic studies in *Ricinus communis* L. *J. Genet.,* **19** : 373 - 389.

Peigler, R. A. and Naumann, S., 2003, Revision of the silkmoth genus *Samia*. University of Incarnate Word, San Antonio, *Texas*, pp. : 1 - 242.

Radhika, A. S., Sakthivel, N. and Sahayaraj, K., 2017, Acceptance of tertiary and non-food plants by Eri silkworm, *Samia cynthia ricini* Boisduval (Lepidoptera: Saturniidae). *Mun. Ent. Zool.,* **12** : 127 - 132.

Raghavaiah, C. V., 2003, Prospects of Eri silk (*Philosomia ricini*) production along with castor beans (*Ricinus communis* L.) and tapioca (*Manihot utilisimma*) production in Andhra Pradesh. *Indian Silk,* **42** : 33 - 35.

Rajasugunasekar, D., 2014, Cultivation techniques for *Ailanthus*. In: Transfers of tree cultivation technologies. Buvaneswaran *et al*. (Eds.), Institute of Forest Genetics and Tree Breeding Prdag print Coimbatore, pp. : 19 - 22.

Rajasugunasekar, D., Menason, E., Geetha, M. and Shanthi, A., 2012, Randomly amplified polymorphic DNA (RAPD) marker analysis in *Ailanthus excelsa*. *Cibtech J. Biotechnol.,* **1** : 32 - 37.

Ramana, P. V., Lavanya, C. and Ratnasree, P., 2005, Combining ability and heterosis studies under rainfed conditions in castor (*Ricinus communis* L.). *Indian J. Genet. Plant Breed.,* **65** : 325 - 326.

Rao, P. V. R., Shankar, V. G. and Reddy, A. V., 2009, Variability studies in castor (*Ricinus communis* L.). *Res. on Crops,* **10** : 696 - 698.

Richharia, R. H., 1937, A note on the cytogenetics of *Ricinus communis* L. *J. Agric. Sci.,* **7** : 707 - 711.

Rogers, D. and Appan, C., 1973, *Manihot, Manihotoides*, Euphorbiaceae. Flora Neotropica. Hafner Press, New York, NY.

Rogers, D. J. and Fleming, H. S., 1973, A monograph of *Manihot esculenta* with an explanation of the taximetrics methods used. *Econ. Bot.,* **27** : 1 - 113.

Saikia, P., 2008, Cocoon and yarn parameters of Eri silkworm *Samia ricini* Boisduval reared on certain host plants. *M.Sc. (Agri)* Thesis, Assam Agricultural University, Jorhat, Assam.

Sakthivel, N., 2018, Foliar constituents of cassava varieties and their effects on rearing parameters of Eri silkworm *Samia cynthia ricini* Boisduval. *Indian J. Entomol.,* **80** : 1381 - 1388.

Sakthivel, N., 2012, Studies on utilization of tapioca (*Manihot esculenta* Crantz) for Ericulture in Tamil Nadu. Ph.D. (Sericulture) Thesis, Periyar University, Salem, Tamil Nadu, pp. : 175 - 178.

Sakthivel, N., 2016, Evaluation of cassava varieties for Eri silkworm, *Samia cynthia ricini* Boisduval. *Mun. Ent. Zool.,* **11** : 2521 - 2534.

Sakthivel, N. and Qadri, S. M. H., 2017, Utilization of cassava foliage for large scale production of Eri silk. *Int. J. Sci. Environ. Technol.,* **6** : 2521 - 2534.

SAKTHIVEL, N., KAMARAJ, S. AND QADRI, S. M. H., 2018, Effect of interchange of cassava and castor leaves on economic traits of Eri silkworm, *Samia cynthia ricini* Boisduval (Lepidoptera: Saturniidae*). Int. J. Sci. Environ. Technol.,* **7** : 1631 - 1636.

SARDOS, J., MCKEY, D., DUVAL, M. F., MALAPA, R., NOYER, J. L. AND LEBOT, V., 2008, Evolution of cassava (*Manihot esculenta* Crantz) after recent introduction into a South Pacific Island system: The contribution of sex to the diversification of a clonally propagated crop. *Genome,* **51** : 912 - 921.

SARKAR, D. C., 1988, Ericulture in India. Central Silk Board, Bangalore, India, pp. : 1 - 49.

SARMAH, M. C. AND CHAKRAVORTY, R., 2005, Screening of new castor genotypes against different insect pests. Non-mulberry silkworms (Volume-II), the 20th congress of the international sericulture commission, 15th-18th December, 2005, Bangalore, India. pp. : 309 - 311.

SURYANARAYANA, 2005, Non-mulberry silkworms (Volume-II), the 20th congress of the international sericulture commission, 15-18 December, 2005, Bangalore, India. pp. : 17.

SARMAH, M. C., AHMED, S. A. AND SARKAR, B. N., 2013, New pests of Kesseru, *Heteropanax fragrans* (Roxb.) Seem a perennial host plant of Eri Silkworm, *Samia ricini* (Donovan). *Mun. Ent. Zool.,* **8** : 900 - 910.

SARMAH, M. C., CHUTIA, M., NEOG, K., DAS, R., RAJKHOWA, G. AND GOGOI, S. N., 2011, Evaluation of promising castor genotype in terms of agronomical and yield attributing traits, biochemical properties and rearing performance of Eri silkworm, *Samia ricini* (Donovan). *Ind. Crops Prod.,* **34** : 1439 - 1446.

SARMAH, M. C., DATTA, R. N., DAS, P. K. AND BENCHAMIN, K. V., 2002, Evaluation of certain castor genotypes for improving Ericulture. *Indian J. Seric.,* **41** : 62 - 63.

SARMAH, M. C., SARKAR, B. N., AHMED, S. A., GIRIDHAR, K., 2015, Performance of C2 breed of Eri silkworm, *Samia ricini* (Donovan) in different food plants. *Entomol. Appl. Sci. Lett.,* **2** : 47 - 49.

SARMH, M. C. AND GOGOI, D. K., 2011, A focus on the Eri silkworm host plant bio-resources and its development through technological intervention and prospects in biotechnology - Hitherto in emerging areas of Seri-biotechnology (course material/invited talks) edited by Chutia, M. and Das, K., CMERTI, Lahdoigarh, pp. : 20 - 31.

SAUD, B. K., ALAM, S., DUTTA, L., NARZARY, B. D. AND BORA, P., 2016, Cassava leaves defoliation for Eri silkworm rearing and its Impact on cassava tuber yield. *J. Root Crops,* **42** : 103 - 106.

SAVY FILHO, A., 2005, Castor bean breeding. In : Borem A. (Eds.) Improvement of cultivated species. Vicosa : Federal University of Vicosa.

SENGUPTA, T., CHAKRAVARTY, D., SENGUPTA, D., SENGUPTA, A. K. AND DAS, S. K., 2008, Screening of some improved castor genotypes for quality parameters in Gangetic alluvial soil of West Bengal. *Agric. Sci. Digest.,* **28** : 268 - 270.

SENTHILKUMAR, N., BORAH, R. K. AND MERU, E., 2006, *Ailanthus grandis* Prain (Simarubaceae) : A promising perennial host plant for Eri culture in Assam. In: Workshop on Eri food plants, 11-12 October 2006, Central Muga Eri Research and Training Institute (CMERTI), Jorhat, Assam. pp. : 121

SETH, S. K., RAIZADA, M. B., KHAN, W. M. A., 1962, Trees of vana mahotsava, F.R.L and Colleges, Dehradun.

SHIFRISS, O., 1960, Conventional and unconventional systems controlling sex variations in *Ricinus*. *J. Genet.,* **57** : 361 - 388.

SINGH, N. P. AND PATNAYAK, B. C., 1977, Nutritive value of *Ailanthus excelsa* Roxb. (Aradu) leaves for sheep. *Ind. Vet. J.,* **54** : 198 - 201.

SINGHAL, V. K., GILL, B. S. AND BIR, S. S., 1985, Cytology of woody species. *Proc. Indian Acad. Sci. (Plant Sci.),* **94** : 607 - 617.

SRIVASTAV, P. K., THANGAVELU, K., IBOHAL SINGH, N. AND SINHA, B.R.R.P., 2005, Inventory and multipurpose use of food plants of wild silkworms. Central Silk Board publication.

SUBRAMANIAN, K., SAKTHIVEL, N. AND QADRI, S., 2013, Rearing technology of Eri silkworm (*Samia cynthia ricini*) under varied seasonal and host plant conditions in Tamil Nadu. *Int. J. Life Sc. Bt. Pharm. Res.,* **2** : 130 - 141.

THANGA, M., SUSIKARAN, S., CHOZHAN, K., VENKATACHALAM, S. R. AND GEETHA, B., 2021, Research impact on different host plants of Eri silkworm *Samia ricini* Donovan (Lepidoptera: Saturniidae). *J. Pharm. Innov.,* **10** : 322 - 325.

TOMAR, U. K., RATHORE, T. R. AND BALA, N., 2019, Enhancing productivity of *Ailanthus excelsa* Roxb. by planting grafted female trees. *Indian For.,* **145** : 1147 - 1151.

TULU, D., ALEME, M., MENGISTU, G., BOGALE, A., SHIFA, K. AND MENDESIL, E., 2022, Evaluation of castor (*Ricinus communis* L.) genotypes and their feeding values on rearing performance of Eri silkworm (*Samia cynthia ricini* Boisduval) (Lepidoptera: Saturniidae) in Southwest Ethiopia. *Psyche.,* 1 - 7.

UGURU, M. I. AND ABUKA, I. N., 1998, Hybrid vigour and genetic actions for two qualitative traits in castor plant (*Ricinus communis* L.). *Ghana J. Agric. Sci.,* **31** : 81 - 82.

UMANAH, E. E. AND HARTMANN, R. W., 1973, Chromosome numbers and karyotypes of some *Manihot* species. *J. Am. Soc. Hort. Sci.,* **98** : 272 - 274.

VIEIRA, L. D. J., 2012, Viability, production and morphology of pollen grains for different species in the genus *Manihot* (Euphorbiaceae). *Acta Bot. Bras.,* **26** : 350 - 356.

WEISS, E. A., 2000, Oilseed crops. 2nd Eds. Oxford: Blackwell Science.

YI, T., PORTER, L. AND GREGORY, P., 2004, Chromosomal evolution in Araliaceae and close relatives. *Taxon*. **53** : 987 - 1005.

ZHENG, L., QI, J., FANG, P., SU, J., XU, J. AND TAO, A., 2010, Genetic diversity and phylogenetic relationship of castor germplasm as revealed by SRAP analysis. *J. Wuhan Botanical. Res.,* CNKI:SUN:WZXY.0.2010-0-002.

ZIMMERMAN, L. H., 1958, Castor bean, a new oil crop for mechanized production. *Adv. Agron.,* **10** : 257 - 288.