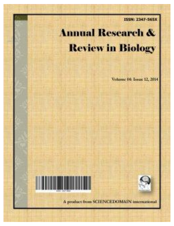

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Tea Seed: A Review

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Authors' contributions

This work was carried out in collaboration between all authors. Author PKP designed the study and wrote the first draft of the manuscript with different aspects of tea seeds i. e morphology, physiology and chemistry of tea seed oil. Author BD contributed the breeding aspect as well as seed baris establishment and seed production. Author RS contributed the management of seed baris along with the quality analysis of tea seed oil of biclonal tea seed stock. Author BG managed the literature searches and handling of collected seeds, storage and packaging. All authors read and approved the final manuscript.

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ABSTRACT

Tea (*Camellia sinensis* (L.) O. Kuntz) is one of the most economically essential beverage crops in all over the world and is considered to be the national drink. Tea seeds are borne in capsules, each containing one to three seeds. Seed is a means for reproduction and always possess variation within groups of seedlings. In nature, variability has an essential role in the production of the crop with quality and quantity. Tea seeds are recalcitrant and shown to lose viability very fast which makes their storage and transportation. In North East India, tea flowers from October to mid-February. Seed development right from flower bud initiation to maturity required 18 months. During seed maturation, the storage of carbohydrates in cotyledons continuously increases, and finally around 30% starch accumulates in tea seed cotyledons. Moreover, flower buds are a strong sink and approximately 46 percent of total photo-assimilates absorbed by developing flower bud. Tea seeds are planted in rows at a depth of about 1.5 cm. The macropile is usually pointed downward or parallel to the ground surface. Product diversification and value addition is currently an area of great interest. The oil extracted from tea seed has almost similar properties of olive and groundnut oils. High-quality detergent, soap, cream and hair oils can be made from tea seed oil.

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1. INTRODUCTION

Tea (*Camellia sinensis* (L.) O. Kuntz) is one of the most economically essential beverage crops in all over the world and is considered to be the national drink. However, due to the uprooting of old seed plantations in different parts of the country; conservation of valuable tea germplasm in the form of seeds has assumed considerable importance [1,2,3]. The seed of tea plant consists of an embryo surrounded by several extra embryonic layers as the covering and is usually develops from the fusion of the nuclei of male and female gametes. Tea seeds are borne in capsules, each containing one to three seeds. Seed is a means for reproduction and always possess variation within groups of seedlings. In nature, variability has an essential role in the production of the crop with quality and quantity. The broad genetic elasticity within the seed population provides the genetic material that allows the continued adaptation of a particular species to the environment. A good seed can be fitted into a wide range of cultural and environmental conditions without much change in its overall performance. For these advantages, there has been a constant pressure by the tea industry for good seeds for which Tocklai Tea Research Institute had to release 15 biclonal seed stocks till now.

A vacuum in the knowledge of various factors responsible for the production of useful seed has created a barrier in this direction. Factors responsible for recalcitrant nature of seed, type of dormancy, occurrence of ecotypes, presence of germination and growth inhibiting factors on the seed coat, presence of chemical substances on the seed coat making them impermeable to water, drought susceptibility, tolerance of high and low temperature and chemical changes during storage etc. are needed through scientific research with minute observations. Similarly to explain the floral biology correctly, the time of anthesis, the dispersal of pollens and compatibility among them etc. are yet to be studied thoroughly.

Tea [*Camellia sinensis* L. (O.) Kuntze] seeds are recalcitrant and shown to lose viability very fast which makes their storage and transportation very difficult [4]. A recalcitrant type of seed needed special care and protective measures during handling, sowing, packing and storage. From pollination to the seed development, particular cultural practices and protective care against pests and diseases are very essential for the production of viable, healthy and improved hybrid seeds. Besides hybrid vigour, components of tea seed can also be exploited as tea seed oil, oil cake as cattle manure. These secondary products are also of great economic value and can be exploited commercially. This paper reviews the available information about tea seed with an objective to compile the information at one place as well as to identify the areas of weaknesses for further studies. Photo-plate -1

2. BIOLOGY OF TEA SEEDS

2.1 Seed Development

The physiological process of seed development can be divided into three main phases. Pollination initiates the first phase of formation of embryonic axis followed by the second phase of seed expansion when both fresh and dry weight increase at a rapid rate due to the accumulation of various reserve materials. In the third and final phase of seed maturation, accumulation of reserves slows down.

In North East India, tea flowers from October to mid-February [5]. After pollination, the fertilized zygote undergoes an extended period of rest and divides only after the endosperm is well advanced [6]. Seed expansion and accumulation of reserve follow this and finally, a mature tea seed is harvested after 10 to 12 months [7]. Blooming of flowers begins from the end of the third flush of the tea growth and continues till the end of winter period; still, the tea flowers mature and dehisce at the same time during October to November [8].

The accumulated starch in the cotyledons and endosperm is converted into soluble sugars for utilisation during germination. The mature embryo of seed lies between two vascularized cotyledons, rich in starch and fatty substances [6].

In the Himalayan foothills, seed development right from flower bud initiation to maturity required 18 months. During seed maturation, the storage of carbohydrates in cotyledons continuously increases and finally around 30% starch accumulates in tea seed cotyledons. Moreover, flower buds are strong sink and around 46 percent of total photo-assimilates absorbed by developing flower bud [9]. The external and internal factors during seed development affect the behaviour of mature seeds [10]. The state of continuum even at full maturity and lack of clear endpoint to seed development in tea as indicated by appreciable contents of soluble protein and total RNA [11] further confirmed the recalcitrant nature of this species. Since the significant type of plant growth regulators like auxin, gibberellins, and Cytokinin are involved during histo-differentiation. In the previous study [12], the vital role of ABA in the seeds during embryo maturation was ascertained. The level of endogenous free IAA in tea embryos continued to increase progressively up to embryo maturation phase, the period during which 90% of the endosperm was consumed by the growing embryo [11]. Seeds are rich sources of cytokinins and a wide range of cytokinins has been isolated from seed tissues [13]. It is believed that cytokinins play a vital role in developing seeds as strong sinks for assimilating [14].

2.2 Morphology

2.2.1 Shape and size

Tea seed is of spherical structure flattened slightly on the side of the hilum. Usually, one seed developed per locule. But sometimes two or more seeds may develop in the same locule. Seed developed from the same locule bear flat or concave surface. Measurement with slide callipers shows that of all size of tea seed, the greater diameter is a linear function of the lesser diameter.

Different seed basis can be distinguished on the same basis of the proportion of large and small-seeded trees [7] found that the improper manuring of orchards increased the proportion of small seeds. However, data available showed that nutrients did not have appreciable effect on the genetical difference between trees bearing large and small seeds. Hence, it is clear that the variation in seed size of a seed stock is primarily due to the varied genetic constituents.

However, seedling size is dependent upon the size of seed. Therefore, small seeds produce smaller seedlings and vice-versa. It does not mean to eliminate all the smaller seeds of a seed *bari* (it is standard source of tea tree used exclusively for seed production i.e. orchard). Instead, a standard seed size is maintained by the tea planters. The maximum germination appears to be associated with the seed of that size which occurs most frequently in a seed *bari*. At the same time, it has also been suggested by different workers that the absolute size of seed was not the deciding criteria for rejecting small seeds. The effect of seed size on the growth of tea seedlings. Results showed that upto one year stage, the bigger seeds developed better seedlings than the smaller ones. Although large sized seeds produced better seedlings in respect of plant height, stem diameter, green weight of shoots and roots in all studies. After three years, the differences were not significant. The amount of food reserve in the seed is an important factor for early growth of the seedlings.

2.3 Physiology

2.3.1 Germination

At the time when seed separates from the parent plant, metabolism is at a low level and there is no apparent growth activity within the seed. During seed germination, cell metabolism increases, the embryo resumes active growth, seed coverings rupture and the seedling plant emerges.

Tea seeds are planted in rows at a depth of about 1.5 cm. The macropile is usually pointed downward or parallel to the ground surface. In "*Bheti*" (i.e. a cylinder of earth about 15 cm in diameter and 20-25 cm in depth around the roots. It is planting method of raising in tea farming) planting the seeds are planted about 20 cm distances in rows and "Bheti" is not necessary, 15cm distance is left between each seed. The seed bed is generally covered by a layer of cut grasses, green leaves etc., so that the moisture content is preserved. Tea embryo does not need any "after ripening" as it germinates readily upon the removal of the seed shell [15].

[16] Conducted a series of experiments on the germination of tea seed. It showed rapid deterioration when stored for more than a few days under normal conditions of temperature and humidity in the tropical lowland. Loss of moisture content resulted the shrinkage of the cotyledon which makes the seed to float in water. [16] suggested three different lines for germination test.

a. Necessity for shelling seeds before planting.
b. Comparative test between freshly gathered and stored seeds, and

c. Germination test for sinkers which became floaters after storage.

[16] Conducted that the seeds from the hard walled capsules were necessary for good germination where the wet method of shelling was used.

[17] tested the germination percentage of normal seeds which were treated with a chemical compound, i.e. triphenyl tetrazolium bromide (Grodex) and an average germination capacity of 67% was recorded. [18] after a series of observation came into conclusion that pre-soaking of the seeds in water for 3 to 5 days and subsequent cracking or removal of their shell markedly speeded up the germination of comparatively fresh seeds. Similar effect was observed in the older seeds, but in them, cracking of seed shell had little effect on germination. Similar effect was observed by [1]. [19] In his unpublished work on germination of tea seed in N.E. India has described that the germination of seed was likely to be associated with resumption of growth activities by the parental trees after the period of winter dormancy and both these phenomena were dependant on the activities of the apical meristem which tends to become synchronous. [1] suggested that the seed bed temperature should always be 25°C and the gibberellic acid was found to be useful for checking the abnormal growth of the seedlings. [20] studied that effect of temperature upon the germination of the seed. Among wide range of temperature tested, a temperature between 20°C -25°C was found to be optimum for tea seed germination. Scarification and pre-soaking of seeds has tended germination. After 18 days of sowing, 66.4% germination was exhibited by scarified seeds against 58.4% in intact seeds. It has been found that mechanical breaking, chemical scarification or manual removal of seed covering almost always improved germination.

The germination efficiency is also greatly reduced by tea seed bug (i.e. *Poecilocoris latus*). The floating seeds are the result of punctures made by this insect. The injury caused by tea-bug is rather difficult to detect with naked eyes. Brownish patches and spots develop on the affected areas which can be observed by a hand lens. The inner tissue of the affected cotyledon turn spongy and a star mark can be seen on the outer surface of the affected cotyledon [21].

2.4 Chemistry of Tea Seed

A number of chemical substances have been detected and extracted from tea seed. The important chemicals are as under:

Albuminoids	8.5%
Starch	32.5%
Other Carbohydrates	19.9%
Fatty Oils	22.9%
Saponin	9.1%
Crude fibre	3.8%
Minerals	3.3%

2.4.1 Tea seed oil

All species of the *Camellia* genus produce an oleagenous seed. Crude edible oil was produced from tea seed in native mills in West Bengal, Himachal Pradesh and Assam and in the Northern region of Indochina [22]. Tea seed oil has been produced on commercial scale in China where in 1958, 180,000 tons of the oil) was produced [23].

The oil extracted from the seeds of *Camellia* species both cultivated as well as other species is termed as tea seed oil. Though *C. sinensis* is cultivated mostly for producing tea of commerce, oil is not usually obtained from this species. Commercial production of oil is derived from species like *C. sasanqua, C. japonica, C. tenuifolia* and *C. oleifera*. Seeds of different *Camellia* species contain 20-70% oil which is comparable to olive (*Olea europaea*) oil in its quality (Tables 1 & 2). It could therefore be a potential substitute for olive oil as well as other edible oils. The production of oil from tea seeds could be considered as an adjunct to tea cultivation in India [24].

Table 1. Oil content in *Camellia* species and other oil crops

Species	Per cent oil (Dry weight basis)
C. sasanqua	60-70
C. japonica	66-70
C. oleifera	40-50
C. tenuifolia	40-50
C. sinensis (Common tea)	20-30
Groundnut	44-50
Olive (Common olive)	15-40
Sunflower	35-48
Mustard	30-48

[22,25,26]

Table 2. Characteristics of various tea seed oils and other accepted edible oils

		Oil characteristics			
Oil crops	**Cultivar/ Type**	**Iodine value**	**Thiocyanogen value**	**Saponin-fication value**	**Free fatty acid content**
1. Tea Seed Oils					
C. sinensis(Assam)	Betjan	87	78	194	3.8
" (Malawi)	Local jat	90	75	198	0.2
" (Turkey)	China hybrid	91	-	192	-
" (Sri Lanka)	-	88.9	-	187.4	5.3
C. sasanqua	(India)	80-92	75-77	188-196	2.6
C. japonica	(Japan)	79	-	187	-
2. Other oils					
Olive		78-90	75-83	186-196	-
Cotton		100-114	61-68	190-198	-
Groundnut			84-100	60-68	188-194

[27]

Table 3. Comparison of oils of tea seed and olive

Particulars	**Tea seed**	**Olive**
Density, g/cc	0.9018	0.9145-0.9190
Refractive index at 25°C	1.4572	1.4670-1.4675
Viscosity, millipoise	314.4	-
Calorific value KJ/g	37.7-39.8	-
Iodine value	88.3--88.9	78-86
Saponification value	98	188-196
Thiocyanogen value	76	79.4
Free fatty acid content	4.5	-

[22]

Table 4. Fatty acids profiles of *C. sinensis* seed oil

Fatty acids	**Tea seed oil**
C16:0	16.50
C18:0	3.33
C18:1	65.97
C18:2	22.17
C18:3	0.30
C20:0	0.53
w-3*	0.30
PUFA	22.47

**(C18:3n-3 +C20:5 n-3 +C22:6 n-3), [33]*

Tea seed also contain golden yellow oil. About 17.3% oil can be extracted from common tea (*Camellia sinensis* L.) and can be substituted for olive and groundnut oils.

The tea seed oil is yellow coloured, free flowing, has pleasant odour and can be stored for 3 months at room temperature without loss in quality [28]. Some physical and chemical characteristics of the tea seed oil and its comparison with other oil crops are presented in Table 3.

Fatty acid composition of *C. sinensis* seed oil consisted of 21.5% palmitic acid, 2.9% stearic acid [29], 56% oleic acid, 22% linoleic acid and 0.3% linolenic acid [30]. The major fatty acid (50% of the total oil) in the *C. sinensis* seed oil was oleic acid [31]. Therefore, with regard to oleic acid, *C. sinensis* seed oil can be ranked between sunflower and olive oil [30]. The proportions of UFAs and SFAs in the extracted oils were 58.1–71.7% and 17.4–23.7%, respectively [31]. This oil had little tendency to dry because of the low C18:2 and C18:3 contents, which cause polymerization [30]. In previous studies, in *C. oleifera* Abel oil, the average content of MUFA, PUFA and SFA were 51.06%, 27.86% and 20.67% and the major component were oleic, linoleic, palmitic and stearic acids, respectively [32]. Also, UFAs content is 75.89%, in which the content of predominate oleic acid and linoleic acid is 73.83% [33].

Recently, work done for characterization of tea seed oil of North East India [34]. Tea seed oil quality analysis of four TRA released and three unreleased bio-clonal hybrid seed stocks were evaluated, namely: 1.TS 462 (TV1x124/48/8) Assam China x Cambod; 2. TS 491(TV1xS.3A/1) Assam China x Assam type; 3.TS 506 (TV1x19/22/4) Assam China x Assam China: Cambod; 4. TS 520 (TV19 x TV20) Cambod x Cambod. Unreleased hybrids viz., China Jat, G202 and ST. 707. The highest Iodine value was recorded in seed stock G202 (85.69). The saponification value was highest in China Jat (184.85). All the bi-clonal hybrid seed stocks had similar refractive index i.e. 1.46. In the fatty acid profiling the major fatty acid of the tea oil is the oleic acid (C18:1), (MUFA), and thereafter linoleic acid (C18:2) and linolenic acid (C18:3). The highest value of oleic acid was observed in TS 520 (43.85) whereas the highest value of linoleic acid was recorded in TS 491 (32.06). The highest mono unsaturated fatty acid (MUFA) was recorded in TS 506 whereas TS 462 and TS 491 showed the highest value (32.47) of (PUFA). Highest value of alfa–tocopherol was noticed in seed stock TS 491 (423.32). In the omega-3 fatty acid profiling we have assessed the following parameters i.e. DHA, ALA, EPA, and ratio of omega-6/omega-3. The lowest omega-6/omega-3 ratio was recorded in TS 520 (56.21) whereas the maximum P/S index was observed in TS 462 (1.28).

2.4.2 Uses

The oil extracted from tea seed has almost similar properties of olive and groundnut oils. High quality detergent, soap, cream and hair oils can be made from tea seed oil. In fact, tea seed oil has been used as an adulterant for olive oil [35]. Tea seeds have been recognized to be a rich source of saponin. "Theasaponin" has been isolated from seeds of *C. sinensis*. Five saponins have been detected in tea seeds namely Theasapogenal A, B, C, D and E [36]. In addition to their good detergent activity, these saponins have been found to be pharmalogically active with pronounced antiexudative and anti-inflammatory properties [37]. Saponin can also be applied in the preparation of photographic films [38]. Tea seed cake (defatted seeds of *C. sinensis*) is used as fertilizer and in Thailand as a crude drug for treating skin diseases [39]. The final residual cake is used as a base in animal feeds [28].

3. BREEDING SEED CULTIVARS

Tea is a cross-pollinated crop and highly heterozygous. It shows severe reduction in fertility and vigourness when closely related individuals are mated. Seed propagation of cross-pollinated cultivars possesses more production problems since such plants tend to be heterozygous to some degree and groups of seedlings are often variable. However, the genetic identity of cross-pollinated cultivars can be maintained to almost the same degree as self-pollinated species if the cultivars are selected to a standard and maintained under conditions preventing cross-pollination from unwanted sources. Such cultivars are not necessarily homo-zygous, but variation is controlled.

Hybrid seed cultivars are first generation progeny between two genetically different plants. Thus, a seed cultivar composed of a large number of genetically distinct plants which is different from a clone with the basic character of adaptability. Seed hybrids are genetically elastic and can be fitted into a wide range of cultural and environmental conditions without much change in its overall performance. Black tea, made from different bushes of a seed population differs in taste and quality, and thus, a section having seed population would give an integration of different tastes. From the viewpoint of marketing, it is very important. Again as the seed hybrids are genetically different, an epidemic outbreak may not cause damage to all the bushes equally, whereas a clone will be more sensitive to such break. Keeping these points in mind, Tocklai Experimental Station, Jorhat, Assam first time in the world initiated breeding programme of developing clonal cultivars and seed stocks. Four polyclonal seed *bari*s each with nine clones were planted inside an isolated forest. One of them, stock 203 (Gaurishankar), was later released to the industry. This stock served the industry until the late 60’s when biclonal seed stocks of superior yield and quality were developed and released to the industry.

In the early years, based on the performances of about 400 biclonal cross progenies, six pairs of clones were vegetatively propagated for planting of micro-seed *bari*s for the production of seed under natural pollination. The seeds produced by these *bari*s were used for trials at different places. The first biclonal stock 378 was released in the year 1968 for cultivation in Darjeeling hills. It is a Chinary stock producing the characteristics of Darjeeling flavor and having a higher yield potential than the Chinary open pollinated populations cultivated in Darjeeling hilly areas. Later on other stocks like 379, 569 and 557 were released for hills and stock 449, 450, 379,462, 462, 463, 464, 491, 520, 506 and 589 for the plains were released to the industry as the better planting materials. These stocks are grouped according to their growing habits, susceptibility to pest and diseases, quantity and quality.

4. SEED PRODUCTION

4.1 Seed Baris and their Establishment

The most important factor which acts directly on the production of seeds is soil. Soil conditions play an important role. The soil must be suitable for tea plantation. Sandy loam to loamy soil with efficient drainage system is the best for this purpose. Before the start of the planting process, the soil should be manured with organic manures like composts, farm yard manure and other organic manures etc.

As all the tea growing areas face a period of heavy rainfall, soil erosion is one of the major problems to the tea growers. Water logging also results the death of seed bearers. To overcome these problems, a sound system of drainage and water management is needed. Before planting the sleeved or bheti plants, cleaning, leveling and manuring should be done.

4.2 Spacing

Spacing is done in such a manner that it would allow seed bearers to cover 60-80% more total bearing surface than the ground area. If the trees are planted closer, the bearing surface will decrease at maturity which in turn will reduce the production of seed bearers. The spacing also varies with the types of seed trees used. The recommended guidelines for spacing of different kinds of trees are as follows:

Spreading type	: 5.5 m to 6.0 m.
Erect type	: 3.5 m to 4.5 m
Chinary type	: 3.0 m to 3.5 m

In biclonal seed *bari*, when both parents are seed bearer, they are planted or grafted alternately in each row. On the other hand, when only one parent is seed bearer, the same is planted in a ratio of 3 seed bearer: 1 non seed bearer. This is found in stock 378 where only one parent is a seed bearer.

4.3 Design

The design for planting of trees in seed *bari*s may be square or triangular. Triangular planting produces greater yield. Square planting facilitates in cultural operation. Therefore, the design has to be worked out carefully for planting biclonal or polyclonal seed *bari*s on the basis of fertility status of the seed bearers. For a polyclonal seed *bari*, clones are positioned in such a manner that each clone gets equal opportunity of cross-pollination with all the remaining clones.

In the case of biclonal seed *bari*s, the clones are of equal seed bearing capacity. Hence, here alternate planting design is recommended for the clones in each row and in either direction.

4.4 Isolation

As tea is a cross-pollinated crop, adequate isolation is needed to avoid unrestricted flow of genes from other tea. Crossing is naturally carried out by small insects with short flying range. To protect the seed *bari*s from foreign pollens, protect the seed *bari*s from foreign pollens, tall hedge of evergreen trees as boundary plants; preferably 10 to 15 meters wide can be raised between tea sections and the seed *bari*s. A barrier can also be raised by planting bushy ever growing trees. However, barrier should not be too near to the seed *bari* and over shading the seed trees.

5. MANAGEMENT OF SEED *BARI*S

5.1 Manuring

Manuring of seed *bari* was first reported by [40]. Good amount of nutrients are used in tea seed development for physiological maturity corresponding to high starch buildup in seed cotyledons. The scientific information on the management of nutrients in seed *bari*s is very scanty. Their management has been scheduled mostly on the basis of practice adopted in some other crops as well as experience of planters. Following scheduled of manuring has been recommended:

Three parts of sulphate of ammonia (12% N) with one part of each of superphosphate and muriate of potash @ 670 lbs mixture per acre. Seed *bari* mixture (S. B.) of NPK @ 3: 1: 2.5 should be broadcasted in seed *bari* tree over 5 year old but the young plants of seed *bari* should receive the young tree mixture @ 1:2:2 [41]. Potash is essential and in dispensable nutrients to the majority of plants and tea is by means an exception [42]. However, all these studies were made without considering the NPK utilization by harvested seeds.

Upto 3-4 years, the management of seed bearers is almost similar as young teas. Seed trees upto 5 years of age are treated with the 2:1:2 types of NPK mixtures [43]. The manuring schedule can be recommended as below:

(a) For trees upto 5 years: 10:5:10 or 10:5:15 type of NPK mixture containing Sulphate of Ammonia, Superphosphate and Muriate of Potash, referred as YT mixture.
(b) For mature tree:

NPK mixture to be applied in the ratio of 1:2:2 or 1:2:3 depending on the level of potash where N to be applied @ 90 kg N / ha.

5.2 Mode and Time of Application

Manure should be applied by a ring method, leaving a circle of 10 cm diameter around the collar unmanured. The fertilizers should be applied in the form of a disc, like a dinner plate with a hole in the centre, so that no manure comes into contact with the collar. The manuring should be done late in April-May before the initiation of flower bud when there is adequate in the ground or respond split during August-September much before flowering begins.

5.3 Green Cropping

To maintain the basic structure of the soil, green cropping is very useful. Green crops which are susceptible to diseases should be avoided. *Cratalaria anagyroides* and *Priotropis cytisoides* are good green crops. *Stylosanthes gracilis*, *Mimosa invisa* or *Calapogonium mucunoides* etc. are grown in lines between the seed bearers as a cover crop to suppress thatch and other weeds.

5.4 Pruning of Seed Bearer

Unwanted lowermost branches can be removed to facilitate cultural operations, seed collection and inspection of the seed *bari*. But it is not advisable to trim all the lowermost branches, because they help in suppressing weed growth and protecting the trunk from sun-scorch. Dead twigs water suckers any unproductive branches should always be removed. At least 30-40% sunlight should fall on the ground in a diffused manner to get high seed yield. The unproductive seed *bari*s could be brought back to the productive stage by heavy pruning (medium prune). This pruning is followed by all cultural operations like lime wash, indopasting (seal the surface of large cuts with a recommended bituminous paint immediately following spraying of copper-oxy- chloride) and proper maintenance of the pruned bushes.

5.5 Drainage

An efficient drainage system is needed in a seed *bari* for better health and good seed yield. Constant cheeling (to remove an unwanted covering or a top layer of the soil i.e. scrape) for seed collection develops depressions around the trees, which should be filled up regularly to avoid localized water logging. In dry areas, watering is an essential need for healthy seed bearer. This can be judged by surveying the soil moisture status as well as rainfall. Seed bearers cannot withstand moisture. Hence, irrigation is essential in stress period for better seed yield.

5.6 Pest and Disease

The germination efficiency is greatly reduced by tea seed bug (*Poecilocoris latus)* Photo-plate 2. The floater seeds are the result of punctures made by this insect. It can be controlled easily by hand collection or by spraying suitable pesticides. Tea is purely an insect pollinated plant. Therefore, the use of pesticide might have a retarding effect on pollinating insects, particularly in the pollination period.

Black rot and thread blight are the two common diseases occurring in seed *bari*s. Thinning out the seed bearers will normally be sufficient to check the disease. In case of severe attack, 0.25% solution of copper fungicide can be sprayed upon both sides of the leaves (against black rat) and twigs of trees (against thred blight).

Raghumala (*Loranthus* spp.) is a partial stem parasite commonly occurring in seed *bari*s. Its houstoria penetrates to the host's conducting tissues and absorb waters and minerals from it. It is necessary to cut off the host branch some distance below the point of attachment. The cut surfaces should be polished and coated with a protective paste Photo-plate 3.

6. SEED COLLECTION AND HANDLING

Prior to seed collection, the ground under each tree should be cleaned and leveled to facilitate seed collection. In case of hilly and sloppy areas, temporary bund of about 1520 cm (6̋ - 8̋) height and breadth can be made surrounding the tree to prevent rolling of seeds too far. The bunds should be removed after completion of seeds collection to avoid localized waterlogging.

As tea seed loses its viability upon drying, it needs very careful handling. Generally, the seeds start dropping from the end of September upto the early January. Tea fruit is allowed to dehisce on the tree and the dropped seeds are collected everyday from the cleaned ground. The collected seeds are passed through a rotary shifter where very small seeds are eliminated. The remaining seeds are allowed to soak water. After 2-3 hours, the sinker seeds are taken out of water and spread on a concrete floor to evaporate the adhering water. The seeds after this floater's test, can be examined by experienced sorters, and the damaged, punctured and cracked seeds are sorted out. The process of sorting is carried out until 90%-95% of the total seeds reach the acceptable level. The floaters are mainly the result of punctures made by tea seed bug. This makes the seed cotyledons to dry which creates air pockets inside the seed coat. The floaters also may be the result of the effect of other factors. Therefore, the floaters and semi-floaters are again treated with moist soil or sand which causes the cotyledons to expand and the locked-up air is expelled. This treatment may continue for two to seven days after which the seeds are again passed through the sinker-floater test. The floaters are discarded.

Tea seed can be sown immediately after cracking of the seed coat or even after collection. The seeds may contain fungus and bacteria which would cause damage to seeds. Therefore, before sowing seeds can be surface sterilized by using 0.1% mercuric chloride by way of dipping the seeds in the solution for 15 minutes, then washing with water and surface drying before packing or sowing. Tea seeds can also be sterilized by copper fungicides (3%).

7. MATURATION, STORAGE AND PACKING

Starch is the primary food reserve in tea seeds. Since starch content remained steady from the end- September till end- October, it can be said the seed maturation and development were completed during this period. Seed maturation from October was also reported by [7] and [8] who observed November as the peak seed harvest period. These observations indicated that intact tea fruits could be collected from the seed trees by the end October / early November and by drying them in the sun, seed can be separated from the capsules.

Although tea is a perennial plant, its seeds have a very short viability period. Tea seed desiccates on prolonged exposure to ambient conditions and hence lose their viability soon. Moulds develop on tea seeds at different lower moisture regimes [44] (Harrison, 1926) and percent of germination gets reduced.

Seed moisture, atmospheric temperature, relative humidity, microbial contamination and insect infestations are the factors affecting viability during storage. If these can be controlled, longevity of seed can be increased [45]. Tea seed bug are the major pest which punctures the seeds causing starriness (floater) [46]. In the starry regions of the cotyledons, the fungal spores and bacterial strains initiate sporulations when congenial atmosphere sets in and thus damage the seeds at significant [47]. Cold storage of tea seed [48] under 100% humid conditions [18] and storage inside charcoal powder under low temperature [49] proved beneficial in maintaining viability. Ripe tea seeds stored in polythene bags at about 5°C, optimally maintained its viability for more than two years and showed high rate of emergence [1].

Tea seeds have been shown to be short-lived and storage ranging from 9 months to six years has been reported with more than 70% germination at the end of these periods by several workers [12,50,51,2]. Tea has been listed by [52] as the species in which recalcitrant behavior has been reported but not confirmed. Tea seed should be used within a few days of picking, but this is not always possible particularly if it has to be transported over long distances. Although many estates may have empirically worked out suitable methods of storage, there is a lack of precise information on the subject. There is not any appropriate and common method for the storing tea seeds. In the traditional method, the tea seeds are preserved for a minimum period in concrete bins or pits in a coal shed covered by a layer of moist sand or sub-soil. [44] Suggested that storage of tea seed in sand or clay was unsuitable for long period. Hermetically sealed tins without any packing materials were found to be the best for this purpose. [53] Leach (1936) reported the possibility of storing tea seeds in pit up to a year. [48] obtained more than 90% germination after 9 months when tea seeds were stored at 4.4°C in wooden boxes lined with papers. [53] showed that the moisture content of tea seeds play an important role in their storage and viability. He successfully stored seeds in sand pits and obtained reasonably high germination rates even after one year. The most satisfactory conditions for the long-term storage of tea seeds at 100% relative humidity and temperature around 5-7°C [54]. [45] Reported that tea seed could be successfully stored at 5 ± 1°C in sealed polythene bag (200 gauges) after treatment with mercuric chloride (0.1% for surface sterilization), copper fungicide (3%) and dust formulation of copper fungicide. The seedling emergence percentage was highest in mercuric chloride treated seed. [55] Suggest that environmental factors in storage period had indirect effects on tea seed germination percentage through seed moisture content. The moisture content of the packing material varies from 10 -30%. If sandy loam sub-soil is used the optimum moisture content would be 10-12% while for powdered charcoal it may vary from 25-30%. Depending on size of the grader used, a kg of graded and stored seed may contain 300-500 seeds [52]. Thus, whatever tea seed packaging method can reduce the risk due to environmental effects listed on seed moisture content, it is expected that the germination is preserved for a longer time [3]. Finally, the results revealed that tea seed if be storage in wet fine sand (5% w/w) and in a darkness cellar with more than 95% relative humidity and ambient temperature below 10°C throughout the storage time, up to about six months can to maintain its viability, approximately.

Packing in wooden boxes of standard size with net content of 20 kg seed, is done by the following method. The packing medium (i.e. charcoal powder/sand/sub soil / ashes etc.) and a layer of seeds (one seed thick) are alternately placed in the wooden box. The mass is covered by brown paper and the lid is down. The moisture content of the packing material used varies from 10-12% in sand and ashes to 20-30% in charcoal powder. Polythene bags are also used to pack small quantity of seeds. Like others, these are also treated with charcoal powder. An additional cloth bag may also be used over the polythene bag to ensure the safe transportation of seed. Chemicals used so far, for packing and storing seeds, were found to be useless.

8. CONCLUSION AND FUTURE DIRECTION OF WORK

Tea seed review has revealed some of the dark areas of ignorance like short life of tea seed, embryology of seed development, diversification of seed and its bi-products and modern packaging technology. Hence, these areas need to be investigated to gain insight for better management of seed production its handling and diversification for higher returns. The uses of the tea seed must be study and exploited for better commercial gains as has been done in China where many medicinal products and daily use product have been developed like toothpaste, face-cream and soaps etc. there is lack of proper system of seed certification to ensure supply of quality seed to growers, the same need to be developed.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

Photo-plate 1

Photo-plate 2

Fig. 1 *Loranthus* grow strongly on tea seed bearer

Fig. 2 *Loranthus* exhibited showy flowers

Fig. 3 Wrapping the branch completely

Fig. 4 Swelling developed due to root fuse completely with the host

Fig. 5 Host for caterpillars

Fig. 6 In severe attack the whole seed bearer dies out

Photo-plate 3

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