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SEED PRODUCTION OF TEAK IN DIFFERENT ORCHARDS OF CENTRAL INDIA: THE PRESENT SCENARIO

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Teak (*Tectona grandis*) is one of the best timber-tree species of the world, and in India, it is the most celebrated timber. The attractive timber qualities are its color and grain, strength, durability, lightness, easy to season, easy for carving works, termite-resistant, fungus-resistant and weather-resistant. The shortage of teak occurs due to the depletion of the natural forest (Troup 1921). Today, teak is planted in nearly 100,000 hectares per annum in India. The first step towards the unveiling of genetics of teak was the establishment of "teak seed origin sample plots" during early thirties. Kedharnath and Matthews (1962) formulated a program for the systematic genetic improvement of teak.

Through selection and breeding, the major objectives of teak improvement programs are to achieve, superior stem form and timber quality, fast growth (height and diameter), a trunk free from fluting, buttressing and epicormic branches, resistance to leaf skeletonizer, defoliator, drought and frost. Based on the rainfall-rate, teak forests have been typified into 5 major classes, very-dry, dry, semi-moist, moist and very-moist with distinct genetic variations. Large quantities of quality seeds is required for planting of teak; to meet up the immediate need, seed stands and seed production areas are identified and therefore maintained. In the procedure, the first step is Plus Tree Selection. A plus tree is a phenotypically outstanding individual combining a number of desirable traits. While selecting plus trees of teak, each superior tree is compared with at least 5 trees within a radius of 50 meters from the plus tree. In order to determine the superiority of the plus tree, a scoring system is adopted for characters like height, diameter, clear bole height, straightness of stem, branching pattern, resistance to pests and diseases, and for seed production. More

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than 3000 hectares of seed stands and seed production areas have been identified in India and are managed for seed production. As yet, ~1,000 plus trees and candidate plus trees have been selected throughout India in different ecotypes of teak (Subramanian *et al.* 1994). Usually bud material is used and clone-banks are established by grafting the buds, to stocks raised from locally available seeds. The establishment of clone banks facilitates subsequent collection of seed and bud material from the plus trees and ensures that the genetic material is available from them even if the plus trees themselves are lost.

The first experimental clonal seed orchard of teak was established at the New Forest campus of the Forest Research Institute, Dehra Dun. Following this, many states have established teak seed orchards is nearly 1,000 hectares (Kumaravelu 1993) which includes pollarding, fertilization and application of growth regulators. The common problem observed in teak seed orchards in India is the asynchrony in flowering among different clones assembled in the orchard. Some clones flower at an early age (e.g. 4–5 years) whereas some others flower only after 10–15 years. A clone belonging to one particular ecotype, suppose dry or moist, included in a seed orchard established in an area of another ecotype, and may not flower in next 40 years or more.

Plantations of teak have been widely established throughout the tropics to produce high quality timber in trees of good growth and stem form. Many factors affect the success of teak planting programs including site, seed supply and seed quality, management and other biological factors such as insects. Site is the primary factor influencing plantation growth and development; with correct site selection, growth and yield can be improved more than 100 % (Kaosa-ard, 1994).

In an experiment to find the effects of sites on the growth of teak, Kaosa-ard (1981) reported that the sites may cover a wide range of climatic conditions, i.e. from the equatorial type to the sub-tropical type with a range of rainfall and temperature of 500-3,500 mm and 2°-48°C (minimum and maximum range) respectively. Soil conditions also vary from infertile acidic to fertile alluvial. A large variation in growth and other characters e.g., stem form, mode of branching, flowering habit and wood quality of the plantation commonly results.

In another set of experiments to find the effects of sites on quality of wood in teak, Kaosa-ard (1993) reported that the wood color and texture in teak is strongly controlled by the planting site. Teak from wetter site conditions, e.g. along river banks or in the lower moist teak forest, is usually darker in wood color than that from drier site conditions. Interestingly, clones of trees from different locations with different wood colors (i.e. dark brown, golden brown, light brown colors, and wood textures, there is no or little significant effect of provenance or seed source on wood color (i.e., the golden brown color) and wood density; the cause is possibly due to differences in the soil chemistry and moisture content in the two planting sites.

To assess the present scenario of the existing teak plantation in 3 states of the Central India, viz. Madhya Pradesh, Chhattisgarh and Maharashtra, the available documents regarding the Seed Production Areas, Seedling Seed orchards and the Clonal Seed Orchards of teak from the concerned state forest departments were collected. The age of the plantations has been divided into 4 categories, i.e., 5 to 10 years, 10 to 20 years, 20 to 30 years and 30 to 40 years. The following data is hereby presented to express the location, age and extents of different SPAs, SSOs and CSOs in 3 states of the Central India, viz. MP, CG and MS (Table 1 - 25; Figures 1 - 25).

Table 1: Location & Extent of Seed Production Area in MP, CG & MS (05-10 Years Old)

State	Area (ha)
MP	0
CG	60.00
MS	0

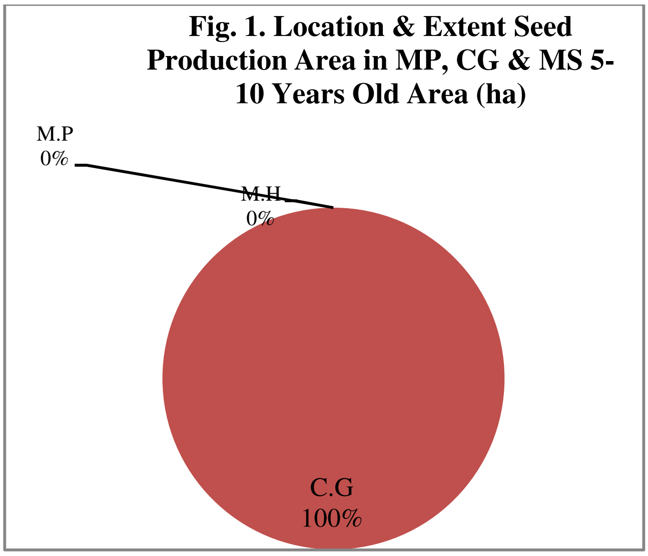


Table 2: Location & Extent Seed Production Area in MP, CG & MS (10-20 Years Old)

State	Area(ha)
MP	782.1
CG	196.35
MS	0

Fig. 2. Location & Extent Seed Production Area in MP, CG & MS 10-20 Years Old Area (ha)

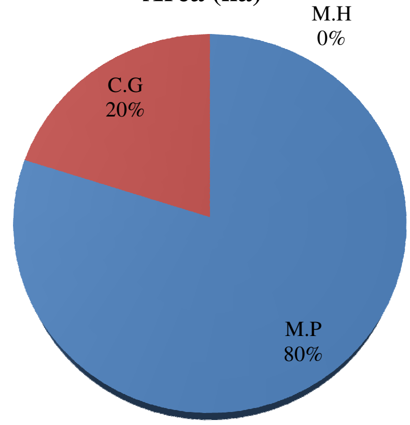


Table 3: Location & Extent of Seed Production Area in MP, CG & MS (20-30 Years Old)

State	Area(ha)
MP	21.0
CG	0
MS	0

Fig. 3. Location & Extent Seed Production Area in MP, CG & MS 20-30 Years Old Area (ha)

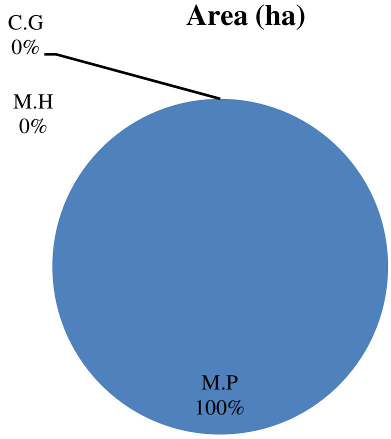


Table 4: Location & Extent of Seed Production Area in MP, CG & MS (30-40 Years Old)

State	Area(ha)
MP	331.00
CG	0
MS	0

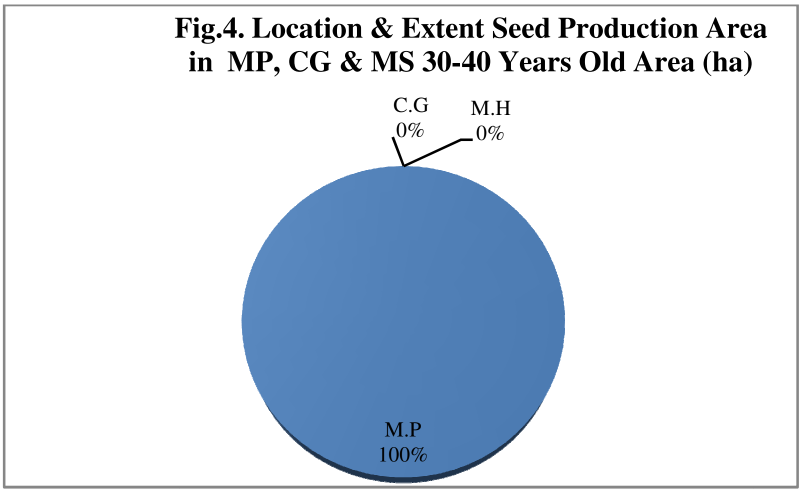


Table 5: Location & Extent of Seedling Seed Orchards in MP, CG & MS (10-20 Years Old)

State	Area (ha)
MP	104.00
CG	146.00
MS	0

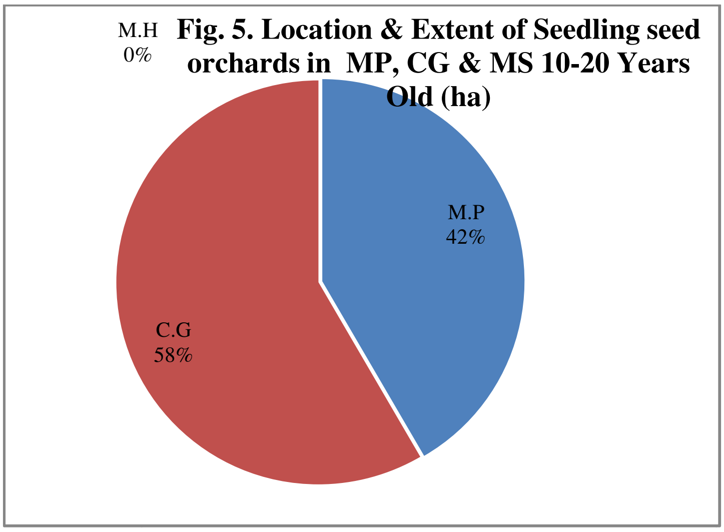


Table 6: Location & Extent of Seedling Seed Orchards in MP, CG & MS (20-30 Years Old)

State	Area(ha)
MP	0
CG	28.00
MS	0

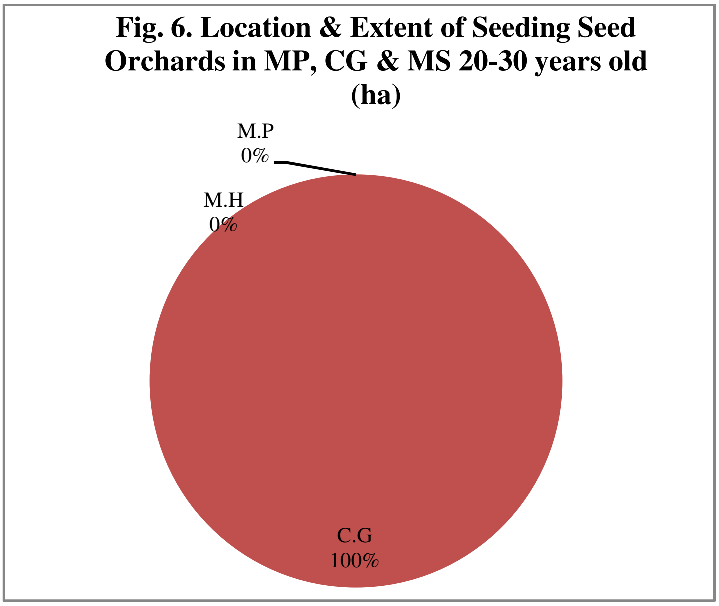


Table 7: Location & Extent of Clonal Seed Orchards MP, CG & MS (10-20 Years Old)

State	Area (ha)
MP	153.6
CG	72.00
MS	69.7

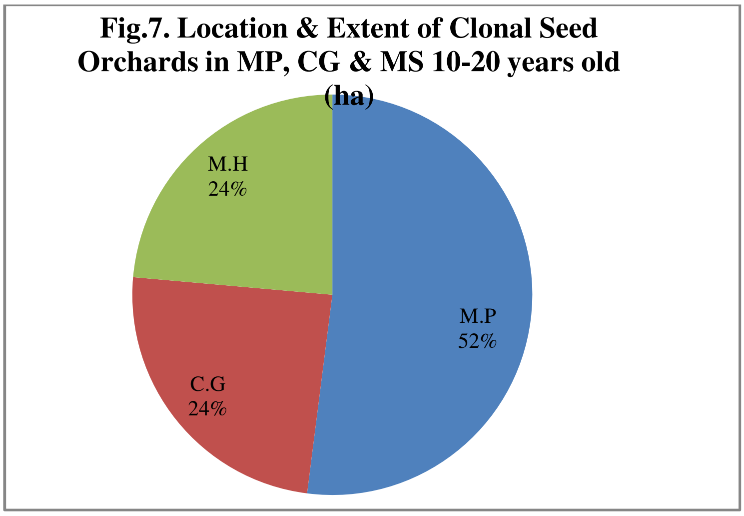


Table 8: Location & Extent of Clonal Seed Orchards MP, CG & MS (20-30 Years Old)

State	Area (ha)
MP	0
CG	0
MS	85.752

Fig. 8. Location & Extent of Clonal Seed Orchards in MP, CG & MS 20-30 years old (ha)

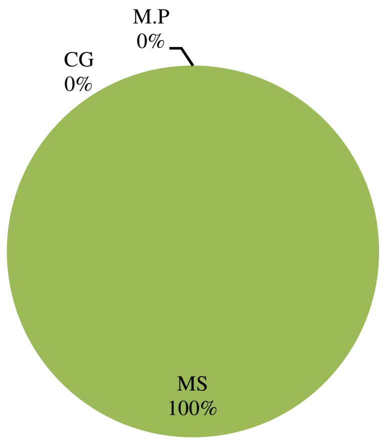


Table 9: Location & Extent of Clonal Seed Orchards MP, CG & MS (30-40 Years Old)

State	Area (ha)
MP	0
CG	0
MS	18.77

Fig.9. Location & Extent of Clonal Seed Orchards in MP, CG & MS 30-40 years old (ha)

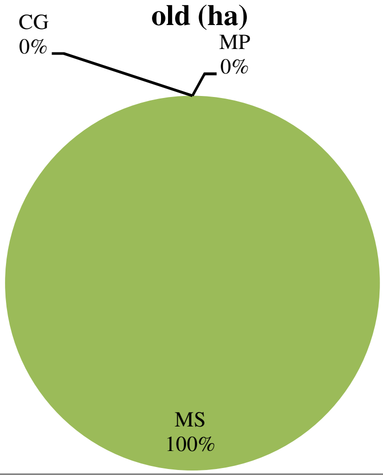


Table 10: Compiled Data of Seed Production Area in MP, CG & MS (05-40 Years Old)

State	Area (ha)
SPA MP	1134.1
SSOs CG	256.35
CSOs MS	0

Fig.10. Compiled Data of Seed Production Area in MP, CG & MS 5-40 years old (ha)

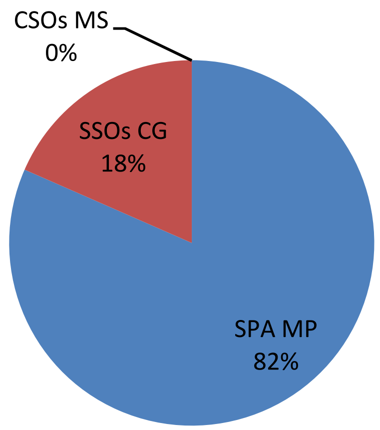


Table 11: Compiled Data of Seedling Seed Orchards in MP, CG & MS (5-40 Years Old)

State	Area (ha)
SPA MP	104.00
SSOs CG	174.00
CSOs MS	0

Fig.11 Compiled Data of Seedling Seed Orchards in MP, CG & MS 5-40 years Old (ha)

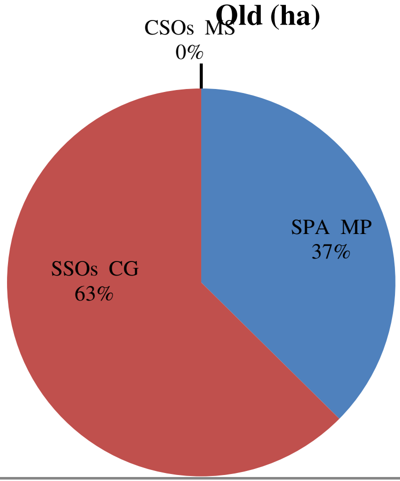


Table 12: Compiled Data of Clonal Seed Orchards in MP, CG & MS (5-40 Years Old)

State	Area (ha)
SPA MP	153.60
SSOs CG	72.00
CSOs MS	174.22

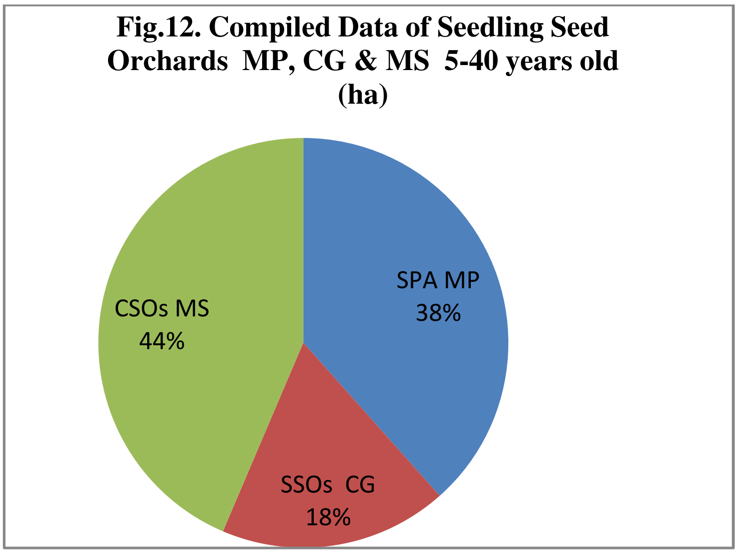


Table 13: Compiled Data of SPA, SSOs & CSOs in MP, CG & MS (5-40 Years Old)

State	Area (ha)
SPA	1390.00
SSO s	175.4
CSOs	399.822

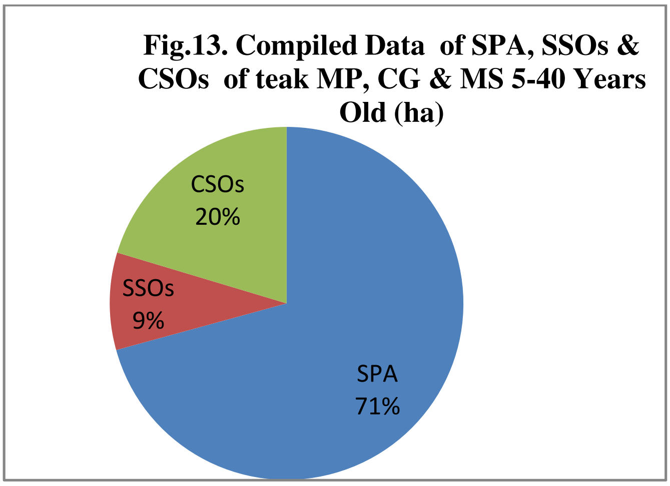


Table 14: Location & Extent of Seed Production Area of Teak in MP (10-20 Years Old)

Name of District / Center	Area (ha)
R & E Center Jabalpur	188.1
Indore	50.0
Betul	245.0
Khandwa	37.0
Seoni	15.0
SFRI JBP	247.5

Fig.14. Location & Extent of Seed Production Area of Teak in MP. 10-20 Years Old (ha)

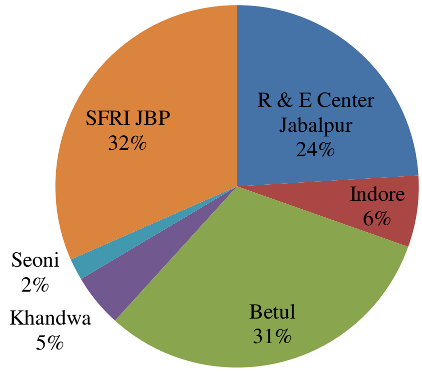


Table 15: Location & Extent of Seed Production Area of Teak in MP (20-30 Years Old)

Name of District / Center	Area (ha)
MP.S.F.D.C.	20
SFRI JBP	1.00

Fig.15. Seed Production Area of Teak in MP 20-30 Years Old (ha)

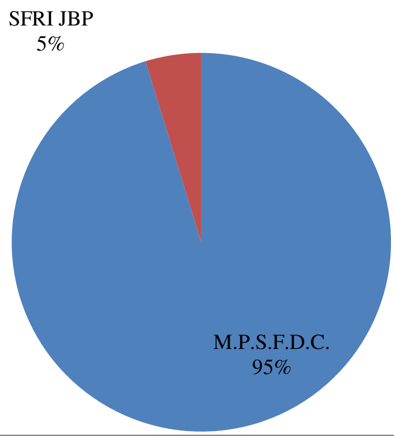


Table 16: Location & Extent of Seed Production Area of Teak in MP (30-40 Years Old)

Name of District / Center	Area (ha)
Harda	120
Hoshangabad	30
MPSFDC	15
SFRI JBP	166.96

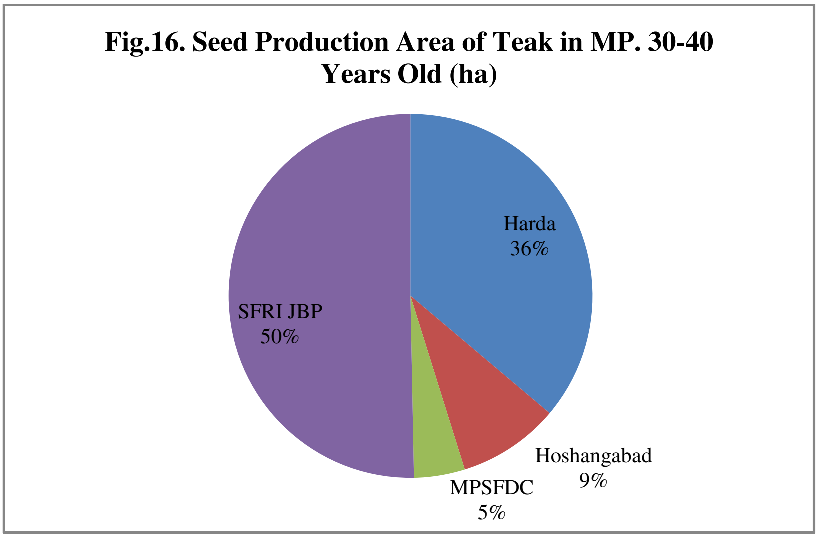


Table 17: Location & Extent of Seedling Seed Orchards in MP (10-20 Years Old)

Name of District / Center	Area (ha)
Betul	20
Bhopal	30
Khandwa	4
Sagar	20
Jhabua	15
Ratlam	15

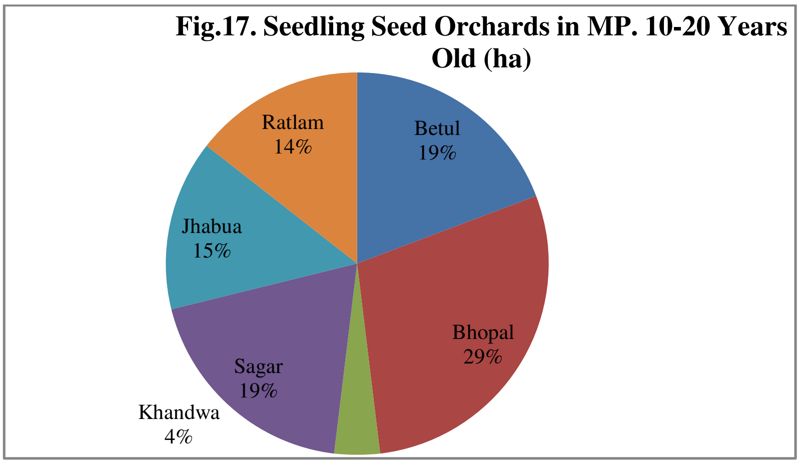


Table 18: Location & Extent of Clonal Seed Orchards in MP (10-20 Years Old)

Name of District / Center	Area (ha)	Name of District / Center	Area (ha)
Jabalpur	10	Seoni	10
Indore	10	Rewa	15
Betul	20	Sagar	20
Bhopal	20	Jhabua	3.6
Gwalior	4	Ratlam	20
Khandwa	21		

Fig. 18. Clonal Seed Orchards in MP 10-20 Years Old (ha)

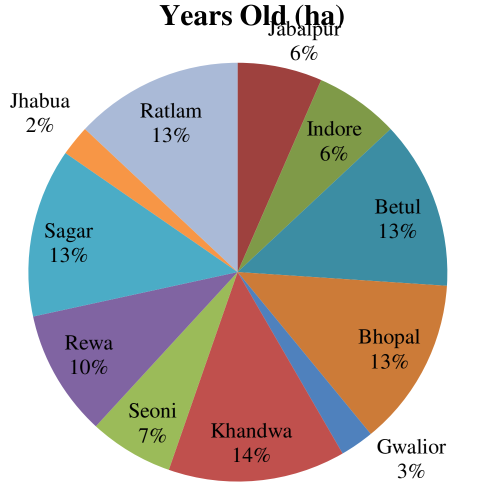


Table 19: Seed Production Area of Teak in CG (10-20 Years Old)

Name of District / Center	Area (ha)	Name of District / Center	Area (ha)
Suma / Pakela Jagdalpur	50.00	Korba / Pali SPA	12.00
Dantewada / Chandenar Jagdalpur	20.00	Korba / Chatuabhona-A SPA	14.17
Beejapur / Bhopalpttnam Jagdalpur	50.00	Korba / Chatuabhona-B SPA	6.00
Bilashpur / Khondra SPA	30.00	Korba / Chatuabhona-C SPA	4.18

Fig. 19. SPA of Teak in CG 10-20 Years Old (ha)

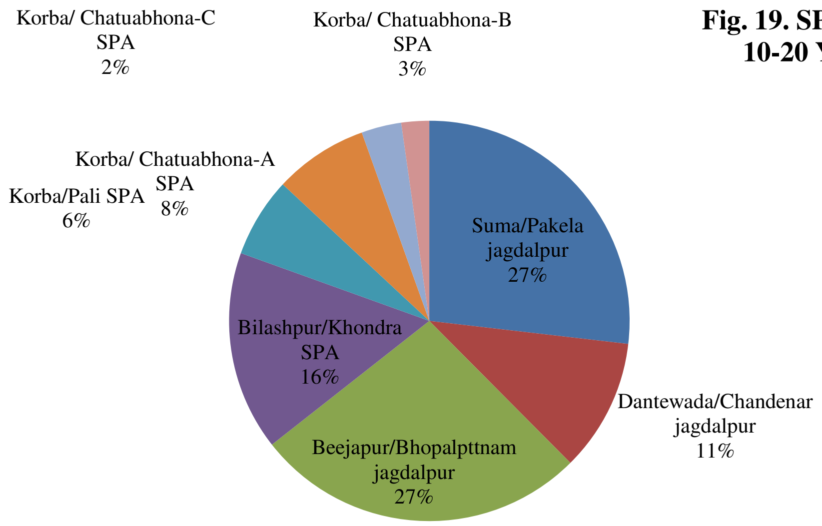


Table 20: Location & Extent of Seedling Seed Orchards in CG (10-20 Years Old)

Name of District / Center	Area (ha)	Name of District / Center	Area (ha)
Bastar / SSO Erikpal	25.00	Bastar / SSO Cholnar	20.00
Bastar / SSO Dodarepal	35.00	Bilashpur / Ghashipur Seeding SeeOrchard	10.00
Bastar / SSO Cholnar	20.00	Bilashpur / Ghashipur Seeding SeeOrchard	11.00
Bastar / SSO Erikpal	25.00		

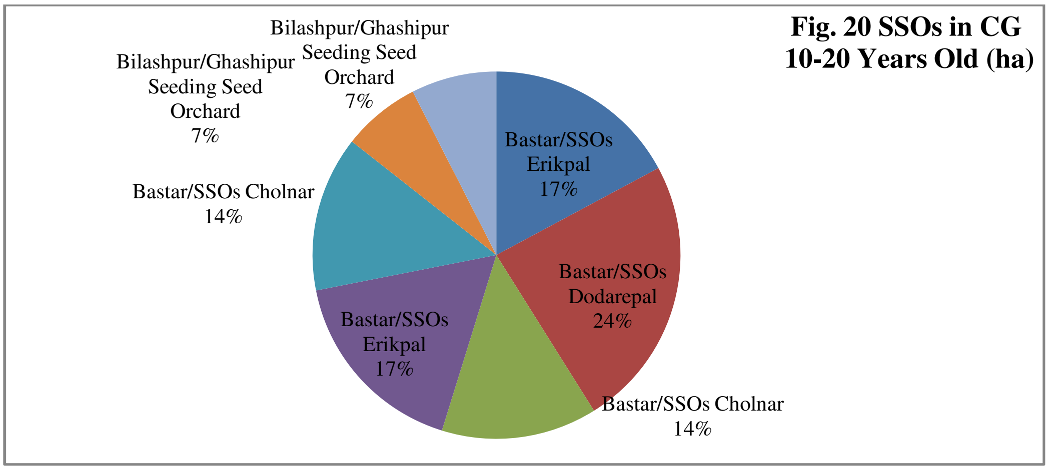


Table 21: Location & Extent of Seedling Seed Orchards in CG (20-30 Years Old)

Name of District / Center	Area (ha)
Bilashpur / Podi Clonal Seed Orchard	15.00
Raipur / Pacheda SSOs	3.00
Raipur / Mura SSOs	10.00

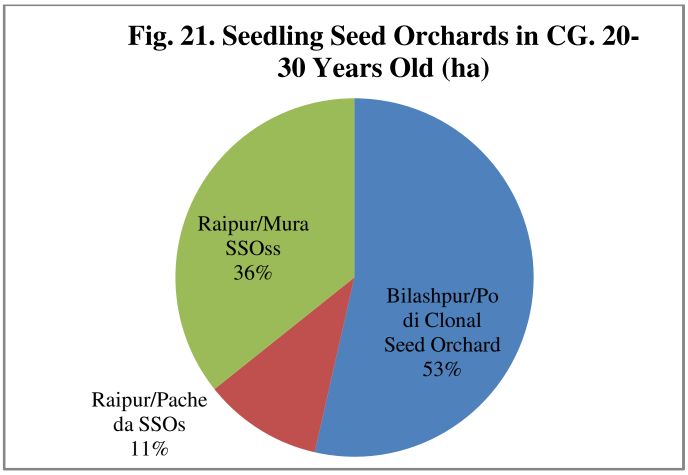


Table 22: Location & Extent of Clonal Seed Orchards in CG (10-20 Years Old)

Name of District / Center	Area (ha)
Bilashpur / Podi	15.00
Raipur / Baktara CSOs	10.00
Raipur / Godhi CSOs	10.00
Raipur / Pacheda CSOs	20.00
Raipur / Mura CSOs	10.00
Raipur / Baronda CSOs	7.00

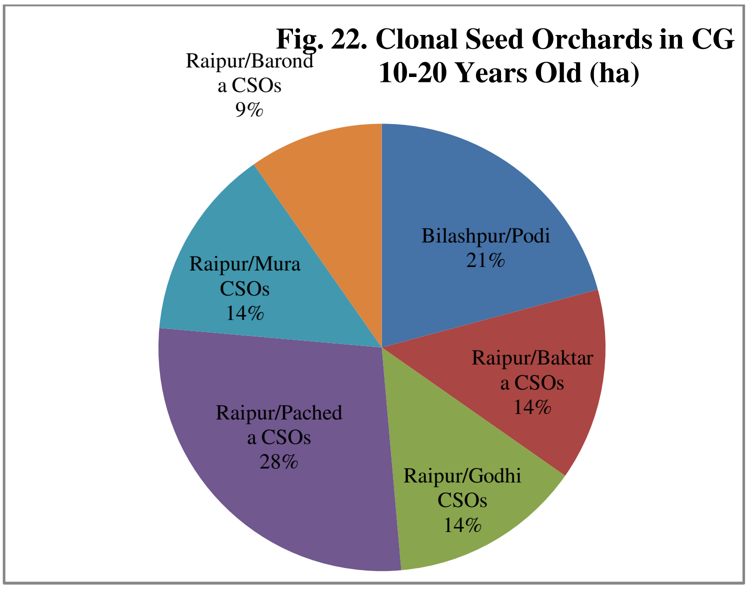


Table 23: Location & Extent of Clonal Seed Orchards in MS (10-20 Years Old)

Name of District / Center	Area (ha)	Name of District / Center	Area (ha)
Research Phondiye Majgav	2.5	Jalgaon / Parola	7.50
Research Phondiye	7.2	JALNA/JALNA	6.5
Phondiye Majgav	1	RES.Wada Dist. Palghar	4.50
Jalna / Jalna	2	Pune	5.0
Nandurbar / Navapur	11.50	Bhandara Research Center Sakoli	22.00

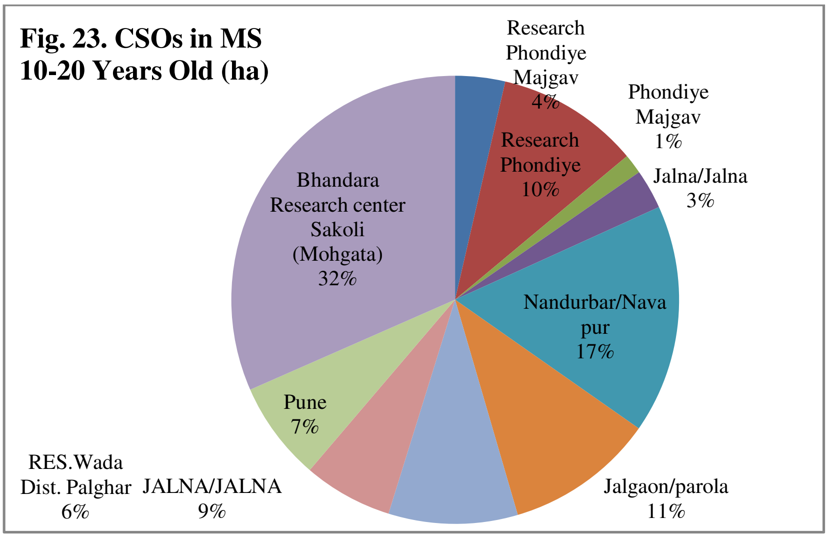


Table 24: Location & Extent of Clonal Seed Orchards in MS (20-30 Years Old)

Name of District / Center	Area (ha)
Research Phondiye	15.00
RES.Wada Dist. Palghar	31.752
Bhandara Research Center Sakoli	39.00

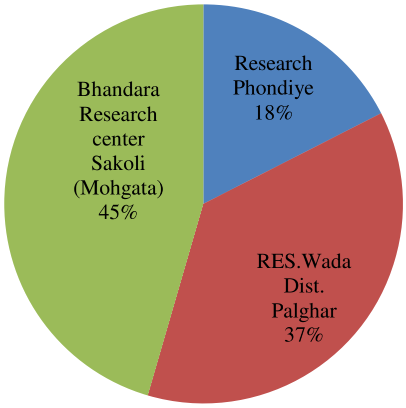
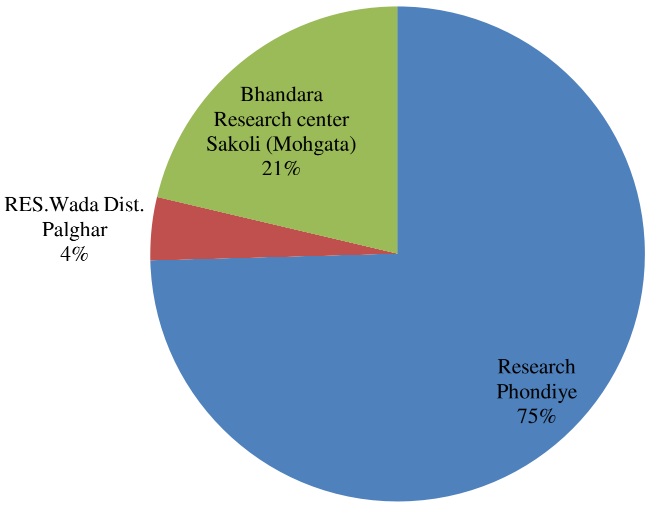


Fig.24. Clonal Seed Orchards in MS. 20-30 Years Old(ha)

Table 25: Location & Extent of Clonal Seed Orchards in MS (30-40 Years Old)

Name of District / Center	Area (ha)
Research Phondiye	14
RES.Wada Dist. Palghar	0.77
Bhandara Research center Sakoli	4.0

Fig. 25. Clonal Seed Orchards in MS 30-40 Years Old (ha)



Discussion

Teak (*Tectona grandis* Linn. f.) is an important timber species preferred all over the world because of its versatile range of uses (Katwal, 2005). Its matchless timber properties include strength, workability, attractiveness & lightness, resistance to termite, fungus and weather, as well as seasoning capacity without splitting or cracking. Teak occurs in natural forests between 9° to 26° N latitude and 73° to 104° E longitude, which includes southern and central India, Myanmar, Laos People's Democratic Republic and northern Thailand (White, 1991). The species is a dominant component of diverse forest types. For instance in India, teak forests are spread over a large geographic area of 8.9 million ha which range from very dry to very-moist types. As a consequence, natural populations exhibit great genetic variability for economically important traits (Katwal, 2005). In fact, the Indian subcontinent is considered the center of diversity for teak because of the huge genetic variation for economically important traits such as bole form, timber quality, biochemical traits and others (Anmol Kumar *et al*., 1997). Further teak is emerging as one of the predominant plantation species in the Indian subcontinent as well as in 30other countries of tropical Asia, Africa and Latin America. Though teak plantations account for 5-8 per cent of the total forest area in the tropics (Ball *et al*.1999), about 90 per cent of the quality hardwood plantations for timber production belongs to only teak (Granger, 1998). As per 1990 data, globally, area under teak plantations was 2.2 million ha, with 94 per cent in Tropical Asia, especially in India and Indonesia, followed by Tropical Africa (about 4.5 %) and remaining area in Tropical America (FAO, 1995). Presently about 1.5 million ha of teak plantations exist in India and around 50,000 ha are raised annually (Subramanian *et al*., 2000). This has resulted in a huge demand for quality planting stocks in astronomical quantities. Genetic improvement of teak in India, started in the year 1954, has focused mainly on identifying phenotypically superior trees from diverse growing regions and deploying them as vegetatively propagated clones in seed orchards (Gunaga and Vasudeva, 2005). Seed orchard is essentially a collection of phenotypically superior and diverse individuals of a species, which is silviculturally managed to produce genetically superior seed crop through Phenology and Climate Change 180 the process of open pollination (Askew, 1986). Establishment of seed orchards using superior clones from diverse regions has been an important strategy of genetic improvement program of teak. It is assumed that the offspring developed through a random mating among the superior types would also be genetically superior. The main purpose of establishing seed orchard is to mass-produce such genetically superior seeds, which are easily accessible and collectable. Thus, seed orchards form an important link between ongoing tree improvement program and commercial planting activity. The establishment of seed orchards would be a genetic dead-end unless full potential of an orchard is realized through harvesting of genetically improved seed crops. Unfortunately, low fruit production in clonal seed orchards has been an important limitation in teak improvement programs of India and worldwide (Gunaga and Vasudeva, 2005; Indira, 2005).

Despite extensive planting program and the importance of increasing fruit production in seed orchards, little is known about the clonal variation for reproductive biology of teak. To use floral traits as a criterion while selecting the clones, it is essential to understand their genetic control. Hence, in order to achieve better genetic gain, it is imperative to assess variation and genetic control of the floral and fecundity traits in an orchard. However, in general, reproductive traits have been consistently ignored while selecting plus trees of teak as well as while upgrading the existing seed orchards. There is only one report on the extent of genetic control of floral features in teak (Hanumatha *et al*., 2001). Perhaps the only study that focuses on estimating the genetic parameters of flowering phenophases in teak was published by Gunaga and Vasudeva (2005). In their study the authors have assessed the clonal variation for flowering phenology and estimated the extent of genetic control over flowering phenophases.

Studies of the reproductive biology and pollination in teak (Hedegrat, 1973; Kaosa-ard, 1991) have shown that teak is predominantly an out crossed species and pollinated by insects. Isozyme analysis of seeds from different clones by Kjaer and Suangtho (1995) has confirmed these results. Self incompatibility and short stigmatic receptive period (which ranges for just about few hours in one morning) are the main reasons for higher out crossing rates (Hedegrat, 1973).

The assumption made while establishing a seed orchard is that diverse genotypes are highly compatible and completely overlap in their flowering phenology and the process would lead to big genetic gain. Synchronous flowering among different clones helps to achieve random mating (Panmixis) and hence good seed output. Further, it also reduces the foreign pollen contribution in the process of pollination, if any. In general the following requirements are assumed to be fulfilled in an idealized seed orchard (Askew, 1986, Vasudeva *et al.* 1999)

- The orchard is completely isolated from the influence of undesirable pollen from outside.
- Natural self-pollination occurs only in insignificant amounts.
- Clones are equally productive in male and female flowers (in case of unisexual species)
- Pollen flight and female flower receptivity coincides especially in monoecious types
- The gamete contributions of the parents are in the same proportions as they were in the orchard

- The pollen contributions to the seed crop are either uniform for all parents or that they are in similar proportions to the seed crop.

Unfortunately, the above assumptions have not been tested among established clonal seed orchards. It is well known that in a seed orchard, the levels of variation for reproductive traits among the constituent genotypes influence fruit production. Further, the variation in flowering behavior among the clones influence the extent of gene exchange between clones and consequently the genetic composition of the seeds produced (Gunaga and Vasudeva, 2002; Vasudeva *et al.,* 2005). Hence, understanding variation for reproductive phenology is fundamental to the successful operation of any seed orchard. Since superior genotypes identified from diverse regions are used in a clonal seed orchard (CSO), understanding the flowering phenology of the constituent clones becomes imperative to achieve maximum synchrony. A large of number of reports is available for temperate species, which document asynchronous flowering among the clones in a seed orchard, especially among monoecious species (Gunaga, 2000; Vasudeva *et al.,* 2001). Any factor that affects the seed production in seed orchards would be a hindrance for logical end of tree improvement programs (Griffin, 1984). Therefore, any variation in flowering phenology within a seed orchard can potentially alter the quantity as well as genetic quality of fruits (Sedgley and Griffin, 1989). Although, there seems to be a direct association between the extent of flowering synchrony among the constituent clones and the fruit production in a seed orchard, surprisingly, there are very few reports in India that focus on these issues. A few authors, however, have also identified this gap of information earlier (Subramanian *et al*., 1994; Nagarajan *et al*., 1996; Radhamani *et al*., 1998, Gunaga and Vasudeva, 2002). Anmol Kumar (1992) has reported that flowering among local clones belonging to the Maharashtra was early as compared to the clones from other parts (provenance) of India. Rawat *et al*. (1992) have reported that flowering in teak seed orchard established at New forest, Dehra Dun, Northern India was asynchronous and recognized that these patterns may cause lower fruit production in the seed orchard. A few reports on these lines are also available in south East Asia. For instance, Palupi and Owens (1998) have shown asynchronous flowering among clones of teak at clonal seed orchard established at East Java of Malaysia. A lack of a suitable tool for an objective measurement of flowering synchrony among different clones has also contributed to the negligence. Hence there is a need for development of objective criteria to evaluate flowering phenological events. In this chapter we firstly bring out patterns genetic variation for reproductive phenology in teak seed orchards; review a novel method of computing the overlap of flowering among individuals in an orchard and discuss its implications to seed orchard fertility from a management perspective.

Genetic improvement of teak has focused mainly on identifying phenotypically superior trees from diverse growing regions and deploying them as vegetatively propagated clones in seed orchards. One of the most important aspects in a seed orchard is the synchrony among the clones for reproductive phenology. This will decide the extent of random mating among the constituent clones and hence the genetic gain in the resultant progeny. Although, there seems to be a direct association between the extent of flowering synchrony among the constituent clones and the fruit production in a seed orchard, surprisingly, there are very few reports in India that focus on these issues. A lack of a suitable tool for an objective measurement of flowering synchrony among different clones has also contributed to the negligence. Hence there is a need for development of objective criteria to evaluate flowering phenological events. The patterns genetic variation for phenology in teak seed orchards have shown that the reproductive initiation events have strong genetic basis and show moderately high heritable values. A novel index to measure flowering among individuals in an orchard has been developed and the experimental verification of the same has shown that there is a large asynchrony among the clones guided by the provenance influence.

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