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A Review: Clonal and Plantation Trials of Eucalyptus in India

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ABSTRACT: Eucalyptus is a diverse genus of flowering trees of a Myrtaceae family and it is a fast growing tree species widely planted in the Tropics mainly for the purpose of pulp wood for paper and rayon. As a short rotation and fast growing nature, this species is widely preferred by farmers, where there is a great demand. This review article is presented to compile all the updated information on its clonal and plantation trial in India for its quality, growth, uses and other different parameters. The main challenges to establish eucalyptus plantation in water scarcity areas is more concern due to high consumption of water and nutrient by some eucalyptus species. There is a need of technical and high-tech farming programmes to handle clonal germplasm of eucalyptus as commercial basis. The increasing demand of consumption of fuel wood should met through sustainable improvement of land and appropriate farming strategies. This review article is undertaken to evaluate the different clonal and plantation trial of Eucalyptus in Indian conditions for further their selection and multiplication.

Keywords: Eucalyptus, clones, clonal trial, quality parameters, growth parameters

INTRODUCTION

The genus Eucalyptus is belonging from Myrtaceae family of Australian origin having more than seven hundreds species (Brooker, 2000). The somatic chromosome number in Eucalyptus is 2n = 22. It is a cross pollinated species resulting in wide variation and heterozygosity in the population. In view of paper and pulp industry its woods are most valuable and naturally plant having wider adoptability and faster growth. The plant having smoothly, fibrous and stringy bark, leaves of Eucalyptus are evergreen and oily glands but in case of some tropical species plant leaves possess senescence in the dry season and the term "cap" or operculum when flower's petals & sepals are fused. The fruit of Eucalyptus is a capsule which is commonly known as "gumnut". Plant is varies in size and habit from shrub to tall trees (10 to 60 m). In the timber industries wood of Eucalypts is an important and valuable source for the production of pulp and paper, charcoal, energy, furniture, and housing. In Indian continent the pulp and paper industries consumed maximum raw material of forest based tree species. The production of papers and paperboard, rayon and news print are primarily based on pulpwood of forestry tree species in which Eucalyptus is a major source.

Production of genetically improved clonal plantation stocks of Eucalyptus can improve the quality of produces such as wood for paper and pulp, leaves for oil extraction and other medicinal value (Lal, 2001). It is found that farmers are easily adopt and grow the Eucalyptus species due to its fast growing nature and wide demand by the pulp and paper industries as well as pole for building construction (Saigal and Kashyap, 2002; Behera, 2016). The productivity of Eucalyptus varies from country to country with changing climatic, edaphic and geographic conditions. The productivity level from clonal plantation of Eucalyptus in Congo, Brazil and Papua New Guinea ranges from 80-90 m^3/ha/year (Ugalde and Pe-rez, 2001), whereas in Indian conditions, it ranged from 6 to 10 m^3/ha/yr in seed route plantations (Lal, 1993) to 20 to 23 m^3/ha/yr in rainfed areas and 50 m^3/ ha/ yr in clonal based plantations (Lal, 2001; Kulkarni, 2002). In case of total productivity the Indian forests are in critical situation *viz.* produces only 15 million m^3/ha/year of industrial timber and 195 million m^3/ha/year of firewood. In India by 2020 AD the requirement of various woods were needed to be 437 million tons for fuel wood and charcoal, 37 million m^3 for industrial wood, 33 million m^3 sawn timbers, 5.7 million m^3 pulp and paper wood and 1.3 million tons for wood based panels (Parveen *et al.*, 2010). It was also reported that in case of pulp wood it will be reached up to 100 t/ha (Kulkarni, 2014). There are limited options to meet the ever-growing wood demand either by increasing the total forest covers or increasing productivity of man-made forests substantially. The farmers target and needs always higher as they predict therefore, the reforestation to be carried out only with genetically improved planting material, which could easily be done either by developing artificial hybrids or clones with substantially higher productivity. The production of pulp, paper, furniture, cellulose and poles mainly relevance to wood based industries and its need meets from Eucalyptus plantation. It finds suitability as a feedstock for the production of bio-fuels and production of energy from charcoal, which reduces

emission of greenhouse gases. In India millions of Eucalyptus seedlings are planted year by year but productivity level has not been achieved yet with the expected yield basically due to poor quality of planting stock. On the other hand, significant improvement in yield has been achieved in many countries through using of improved breeding and genetic tools with applying of clonal forestry. Hence, there is need to identify, adopt and grow the genetically superior clones having potentiality for higher pulp recovery coupled with higher productivity.

A. Uses and importance of Eucalyptus

As Wood and Pulp: It was studied on the pulping yield, bleaching, papermaking and printing quality of Eucalyptus to analyse and compare the following three species as: *E. globulus* was better than *E. grandis* and which in turn better than *E. tereticornis*. It was also found that many other uses of eucalypts which are economically important to small-scale industries including oil, honey production and cut flowers. Species like *E. globulus* reported as a major commercial source for essential oil and *E. tereticornis* as a major source of pollen in apiculture Pant *et al.* (1980). Eucalyptus is well known for its solid wood, paper and pulp production. Eucalyptus timber is widely used as a construction material as poles for scaffolding, lines transmission, railway sleepers, bridge and furniture making. The species *E. tereticornis* was reported as good and qualitative characteristics for Pulp and paper making with using of high density plantation (Tiwari and Mathur, 1983).

As oil:- The extraction of Eucalyptus oil from extracted from leaves is widely preferred as raw materials in cosmetic and pharmaceutical industries. Oil of *E. globulus* have moderate antimicrobial activity both on Gram-negative and Gram-positive bacteria and a bacteriostatic activity against all strains tested except *Pseudomonas aeruginosa* (Ait-Ouazzou *et al.* 2011). Antimicrobial and anti-inflammatory activities were reported by using of eucalyptol (leaves extract).

As antiseptic: It was noted that Eucalyptus herb act as to treat colds, flu, sore throats, and chest infections including pneumonia and bronchitis (Williams *et al.* 1998). Eucalyptus also used as antiseptic and to treat the infections related to respiratory system (Chevallier, 2001).

As anti-inflammatory, analgesic, and antipyretic: Anti-inflammatory, analgesic, and antipyretic properties of Eucalyptus oil was reported by Silva *et al.* (2003). The role of eucalyptol as inhibitor of the production and synthesis of tumor necrosis factor-α (TNF-α), interleukin-1β (IL-1β), leukotriene B4, and thromboxane B2 in human blood monocytes (Juergens *et al.* 1998). It was also observed the suitability of eucalyptol of strong inhibitor of cytokines for the long term treatment of airway inflammation in bronchial asthma and other steroid-sensitive disorders**.** Anti-inflammatory activity of eucalyptol was evaluated in patients with severe asthma and suggested the efficacy of this molecule for its use as mucolytic agent in diseases (Juergens *et al.* 2003). The impact of Eucalyptus extract on skin was found identical which was reported by Ishikawa *et al.* (2012).

As agronomic and healthcare properties: Agronomic (as herbicide and insecticide) and medicional (as antimicrobial, antibacterial, antiseptic, antiinflammatory and antifungal) properties and as well as healthcare properties of eucalyptus oil were discussed by Parul *et al.* (2021). The germination inhibitory properties of *Eucalyptus citriodora and Eucalyptus tereticornis* oil on congress grass (*Parthenium hysterophorus*) was reported by Kohli *et al.* (1998).

B. Clonal culture of Eucalyptus for growth and other different parameters

MS medium culture based Eucalyptus experimental trial was carried out at the FRI campus, Dehradun for *in vitro* clonal propagation of FRI-6 and collect twigs from FRI-6 of F1 interspecific hybrid (*E. tereticornis* × *E. grandis*). MS medium culture was used constituted with BAP and NAA each at 1 mg/l in which sub culturing with BAP were applied on regular basis. The maximum rooting upto 75% was noted with 1/2 MS medium constituted with IBA (1.0 mg/l). Final result of experiment concluded that best growth, stem form and pulp quality was achieved from the FRI-6 hybrid (Joshi *et al.* 2003). Clonal experimental trial was also conducted at three sites such as Tamil Nadu, Kerala and Andhra Pradesh. On these sites total 78 and 27 selections were used related to *E. camaldulensis* and *E. tereticornis* along with 5 natural provenance seed lots and 13 clones. Spacing between rows and trees (2m and 1.5m) were maintained. Experimental result analysed after three year and it stated that most of the clones were selected from *E. camaldulensis* plots of Tamil Nadu site. Commercial Eucalyptus clones (*E. tereticorni*) and seedling control were superior in sense of volume production. The overall mean height (9.1 m) was noted from Sthyavedu (Andhra Pradesh) site, 7 m from Karunya (Tamilnadu) and 5.4 m Kulathupuzha (Kerala). The final result indicate that at the site of Sathyavedu clones of *E. camaldulensis* were much better as compared to other ones in sense of faster growth (Varghese *et al.* 2008). Clonal variation study was worked out for analysis of growth parameter (DBH) of twelve clones of Eucalyptus at Ludhiana (Punjab) (Luna and Singh, 2009). Researchers also studied the diameter growth from clones related to tereticornis (Dhillon and Singh, 2010), whereas clonal variation for growth parameters *ei.* DBH, mid-diameter, height, form quotient and volume at 5.5 years age was studied by Kumar *et al.* (2010 A). This review article mostly compiled detailed study relevance to clonal experimental variation on Eucalyptus for growth, quality and other different parameters at different sites of Indian region.

A field experimental trial was conducted at Hoshiarpur, Punjab to evaluation of 18 clones of *E. teretocornis* for growth parameters. In this experiment RBD design was used. Growth parameters such as plant height, DBH and CBH were analysed and noted

significant variation for these parameters. It was found that genetic gain for height and CBH increased substantially with increasing plant height. The maximum average genetic gain for plant height (159.60%) was recorded which was followed by DBH (110.97%) and CBH (70.34%). At second and third year Clone no. 17 noted maximum DBH over other genotypes followed by clones 14 and 11. Clone 5 showed an upward trend for DBH and maintained its superiority for CBH as the tree height increased. As per recorded data it was found that clone 17, 14 and 5 superior as compared to others (Kumar *et al.* 2010 B). The longitudinal growth strains and basic density of wood was analysed for 5 clones of *Eucalyptus tereticornis*. Result of experiment revealed that the mean longitudinal growth strain for clones ranges from 466 to 876 µm. Significant differences were noted between clones for growth strain and wood basic density. The maximum growth strain and basic density was recorded from clone 10, whereas minimum from clone 3 and clone 7. The differences of growth strain from opposite sides from logs varies from 5 to 200% whereas, two strains possess strong positive correlation and wood basic density and mean growth strains in logs reported moderate positive association (Aggrawal and Chauhan, 2013).

An Experimental trial at Sarapakka, Andhra Pradesh was conducted to study on intra clonal variation of specific gravity and mechanical properties in 4-5 years old trees. Clones (3, 4, 6, 7 and 10) of teretricornis were selected from ITC, Bhadrachalam. The significant difference was noted within the clone for the parameter of specific gravity for all the clones except clone 10. Non significant differences were noted for clone bending properties (MOE, MOR and FS at LP) in green and air-dry condition. The significant differences and highest crushing strength was found for all clones except clone 7. Conclusion of experiment indicate that strength property was not follow the trend of specific gravity and found non significant. Clone 4 noted maximum value for all the properties tested but also found lowest girth. Clone 10 had the highest value for girth for all the trees followed by clone 6 (Kothiyal, 2014). At the Tarai belt of Uttrakhand an experimental trial of Eucalyptus was established under different edaphic conditions to assess the productivity of respective clones. Trials were conducted at following four different sites such as Dhimri, Tanda, Barakoli and Kotkharra. The following three clones (K-25, K-28 and A.P-10) were selected and planted during 2005 in 0.5 ha area at spacing of 2 m × 2 m. Planted area was surveyed after three year. Observation like plant height was taken by using Ravi multimeter. Correlation of diameter and volume between different clones in a plantation area and clonal testing area indicates that AP 10 shows better growth as compared to other clones (Gangwar *et al.* 2015). Clonal trial was established in southern India to evaluate the growth and fertility of 40 *Eucalyptus camaldulensis* clones at the age of four year of planting. In this study growth parameters found differed significantly for 38 clones, whereas 2 clones reported low survival only 40 and 10%. Clones (55%) whose contributing 80% of the fruit had sibling coefficient value (1.4) and they were noted high fecundity value with low fertility variation. A clonal seed orchard was achieved from clonal trial in which clones fertility and its effectiveness were considered (Kamalakannan *et al*. 2015).

There were fourteen clones of Eucalyptus (P-411, P-413**,** P- 286, P- 2136, P- 2049, P- 405, P- 526, P-2155, B- 2153, B- 2153, ERK- 04, JKSC- 08, JKSC-04, JKSC- 02, SRO- 16) and two species pellita & torellina were selected to evaluate the tolerance efficacy against gall at NAU, Gujarat. The analysed data showed that species torellina noted resistant against gall and clones P-411, P-413, P-2136, ERK-04, P-526 with species pellita reported highly tolerant. The negative correlation of gall wasp with growth parameters was found. The growth parameters showed that the clone P-411 noted maximum height and highly tolerant followed by P-413 and P-2136. The clone P-526 which was highly tolerant observed highest average DBH (85.64 mm), average volume (22599.96 cm^3) and average wet biomass (1129.99 kg). The Eucalyptus entries P-411, P-413 and P-526 were observed highly tolerant to gall wasp and B-2153 moderately (Singh *et al*. 2015).

An experiment was carried out at the instructional farm, college of forestry, NAU, Gujarat. In this clonal experiment 20 clones of Eucalyptus (C1 : P72, C2 : P1, C3 : P405, C4 : P413, C5 : P411, C6 : P316, C7 : P498, C8 : P526, C9 : P2136, C10 : P2155, C11 : P3020, C12 : P2045, C13 : P2069, C14 : JK08, C15 : JK02, C16 : SRO16, C17 : B2253, C18 : B2153, C19 : B271, C20 : B288) were planted during September 2009 followed by 2 x 2 m spacing with 3 replication and RBD design. In this field experiment 9 ramets per clone were randomly selected and analysed growth parameters at 5.5 years of plant age. Instrument such as Mantax Blue Caliper was used to note DBH at 1.37 m above of ground level, whereas 1000 Criterion Dendrometer and Electronic Clinometer were used for measure mid-point diameter and height, respectively. The result of study noted that significant variation among 20 clones for growth parameters *viz.*, tree height, DBH, mid-diameter, form quotient and volume of standing tree was noted. Plant height varied from 18.5 to 23.6 m with DBH range from 11.47 to 16.07 cm and mid-diameter ranges from 6.99 to 10.57 cm among 20 clones. The form quotient varied between 0.58 and 0.71 with overall mean of 0.63 at studied site. Volume of standing tree noted from 0.12 to 0.28 m^3. The final conclusion of study revealed that following clones such as C12 (P2045), C17 (B2253), C4 (P413), C8 (P526), C7 (P498), C16 (SRO16) and C11 (P3020) reported superior for early growth attribute and stem form (Behra *et al.* 2016). They also evaluated the data for genetic variability and correlation study of Eucalyptus clones for growth characters at the same above region and clones of Eucalyptus during 2009. By the following of standard procedure total 3 ramets selected randomly for per clone and growth parameters. Experimental data related to growth

parameters were observed at 6 year plant age. The result of experimentation revealed that among different genetic variability volume was found maximum in GCV with 22.67%, heritability with 0.52 and genetic gain with 33.78%. Similarly significant and positive correlation of volume with DBH, mid-diameter, tree height and form quotient was recorded. With the analysis of result it was concluded that volume was found maximum genetic variability and showed positive correlate with all the remaining growth characters. Hence, clones with maximum volume could be used for clonal improvement programme in South Gujarat condition (Behra *et al.* 2017).

At the region of Bagwala, Rudrapur Uttrakhand a trial was established with 21 commercially grown clones of Eucalyptus and select following clones (BCM 7, BCM 271, BCM 288, BCM 316, BCM 411, BCM 413, BCM 526, BCM 2023, BCM 2045, BCM 2070, BCM 2135, BCM 2306, BCM 2313, Wimco 12, Wimco 14, Wimco 15, K 23, K 25, EC 4 and unnamed one belonging to different species of Eucalyptus including a seedling population of locally collected Eucalyptus hybrid as control) to assess the growth and susceptibility of Eucalyptus clones for three biotic agents such as *Leptocybe invasa*, *Cylindrocladium quinqueseptatum* and *Botryosphaeria* spp. RBD design was used with five replications and five trees in each replication. During the first and second winter season wheat crop was grow out as an intercrop. The results indicate significant variation for height, DBH, clear bole length, crown diameter among the tested clones. Ratings of individual clones for growth index (GI), susceptibility index (SI), and composite growth and susceptibility index (GSI) against all three biotic agents also showed the significant variation among clones. The growth and susceptibility index showed that clones Wimco 12, BCM 526 and BCM 316 were superior over other clones (Dhiman and Gandhi, 2016).

At Futala farm, college of agriculture, Nagpur (Maharashtra) an experimental trial on Eucalyptus was carried out during 2011-2015 to evaluate the superiority of clone for its growth performance under dry land conditions by and select nine clones *viz.*, ITC -7, ITC-413, ITC-316, ITC-71, ITC-526, ITC-288, ITC-136, ITC-286 and ITC-3 and which were compared with seedling as check. The result of experiment stated that the maximum significant height recorded from clone ITC-413 (6.62 m) followed by ITC-71 (6.33 m) and ITC-316 (6.32 m), whereas the clone ITC - 136 (5.26 m) had minimum height. In case of maximum mean annual height increment the clone ITC - 413 (1.324 m) was observed also superior. The maximum DBH was attained by the clone ITC - 413 (20.13 cm) followed by ITC - 316 (16.32 cm) and ITC - 71 (15.23 cm). The lowest DBH was attained in ITC – 286 (7.12 cm). Analysed result conclude that the clones ITC - 413, ITC - 316 and ITC - 71 were noted best for cultivation under dry land conditions (Ilorkar *et al*. 2016). An experimental trial was established on *Eucalyptus* spp. at PAU, Ludhiana, Punjab to assess the genetic variability, heritability and genetic advance. In the experimentation following nineteen clones were used C-316, C-411, C-413, C-526, C-2013, C-2034, C-2070, C-2136, C-2188, C-3011, C-3020, C-3021, P-7, P-13, P-14, P-23, P-46, P-48, P-103) with CRBD design with four replications. At the field level following observations related to growth parameters and biotic incidence of gall wasp were noted at eight month of plant age. Parameters such as plant growth, branches numbers and tolerance to gall wasp were observed and indicated significantly differences among the clones. The phenotypic and genotypic coefficients of variation indicate maximum variation for number of galls, volume index and genetic variability for growth parameters. High potentiality of improvement in plant height and volume index was due to high heritability with high genetic advance. Highly significant phenotypic correlations for plant height with volume index, collar diameter and number of branches were also noted by Kumar and Dhilon, (2016).

A clonal trial was carried out on Eucalyptus during 2002 at FRI, Dehradun with 91 seed lots and 13 provenances. Index method was applied to select 47 plus trees. On the basis of field performance three clones were selected for commercial cultivation in the northern site of India. The productivity of recommended clones varied from 14.68 (FRI-ET-32) to 23.04 (FRI-ET-31) m^{-3}/ha/yr and recorded 76% superiority to evaluated genotypes and checks (Kumar *et al*. 2017).

An experiment was conducted at farmer's field in Karnataka to study the clonal variation in selected wood of *E. tereticornis* including specific gravity and anatomical properties from both the regions such as rainfed as well as irrigated. Clones GR-3 and GR-283 was selected as randomly from plantation. The area of plantation of these clones was 5-20 acres. In the plantation spacing for these clones 1.75m x 1.75m was maintained. Each tree was cut at 10cm above ground level. 1 foot long billets were obtained at three heights- bottom, middle and top position. Each billet was cut into a plank from which three radial strips (pith, middle and periphery/ bark) were obtained. Each of these strips was cut into five equal sized blocks (1cm × 1cm) for anatomical studies and specific gravity measurements. The result of study stated that radial variation within the clones did not show a definite pattern with respect to specific gravity. There was a fluctuation in specific gravity from pith to periphery. As observed data relevance to specific gravity indicate as suitable for making of paper and pulping. Result showed that plantation of clones under ranfed site had maximum specific gravity as compared to irrigated site of plantation. The significant values were observed from Inter clonal variation and between localities variation (Shri Laxmi and Rao, 2017). Field experimental trial of clonal plantation of Eucalyptus was carried out at research institute of Mettupalayam to achive high pulp yielder and wood volume clones. In this experiment 27 Eucalyptus clones and 3 species (*E. camaldulensis*, *E. tereticornis* and *E. urophylla*)

were evaluate for pulp quality parameter. As per observed and analysed data clone EC 48 found superior as better quality of wood, paper and biomass production. Clone (EC 48) noted the 48% pulp yield, 19.3% kappa number and 23.20% lignin content which found better over local seed sources. Similarly, this clone also reported as better in sense of burst index, tear and tensile index which indicate the plant strength properties. The maximum calorific value (4314 kcal/kg), fuel index (142.58) and heating value (30.27 MJ/kg) observed from EC MTP 48 clone. Clones EC MTP 48, EC MTP 47 and EC MTP 41 were reported better for growth characteristics *viz.*, diameter at breast height and volume. The final conclusion suggested that the clone EC MTP 48 observed as superior for plantation as noted good pulp quality and productivity Vennila *et al.* 2017).

A clonal based Eucalyptus trial was carried out at Ariyalur district (Tamil Nadu) to assess suitable clone for growth parameter. Field layout was based on RBD design with following 3 replication and 16 ramets. In this experimentation thirty one best clones of Eucalyptus were separated from first generation provenance trials by using of index selection method. Clonal trial was conducted during 2010 by the using of collected superior clones. Observations were recorded up to 3 year and after analysis of result it was revealed that clone C 31, C 9, C 196 and C 17 were found identical as for growth parameters such as plant height, stem girth at breast height and volume (Vijayaraghavan and Sivakumar, 2017).

At the campus of NAU, Navsari (Gujarat) a clonal trial was established in which eighteen clones of Eucalyptus was analysed for growth parameters. As per the layout spacing between clones (2 m × 2 m) were maintained with the following of RBD design and 3 replications. Result of experimentation showed significant variation for growth parameters. Among 18 clones, EC-4, EC-5, EC-8, EC-10 and EC-12 showed superiority for growth and stem biomass. Further, these five clones were assessed for pulp productivity and result noted that the differences were found in pulping yield *i.e.*, about 46 to 48% among five clones were noted. Data revealed that all these five clones found to be superior for both growth and pulping yield and they were suggested for commercial plantation in Navsari agro-ecological situations (Huse *et al.* 2018).

At the Vindhyan region (UP) a trial was established in the year 2016 to identify the suitability of clones in the region. The trial was conducted by the following of RBD design, three replications and spacing of 3 m x 2 m for 19 clones (413, 7, 526, IFGTB-4, K-25, 288, 2013, 2023, 2070, 2136, 3018, 2031, P-13, P-14, P-23, P-32, P-45, P-50, P-66) and three Eucalyptus species (*Eucalyptus hybrid*, *Eucalyptus tereticornis* and *E. camaldulensis*) along with control for 20 treatments. Result was assessed after one year of plantation for growth performance of clones. Maximum GBH was noted from clone 526 (9.04 cm) which was followed by 2136 (8.84 cm), P-50 (8.53 cm) P-14 (8.33 cm), P-32 (8.04 cm), 2023 (7.88 cm) and P-13 (7.81 cm) respectively. In case of height highest value was observed from clone P-50 (4.04 m) followed by 526 (3.82 m), 2136 (3.76 m) and P-13 (3.73 m) over control and other treatments (Srivastav Anubha *et al.* 2018).

At the Tropical Forest Research Institute, Jabalpur, Madhya Pradesh field trials on Eucalyptus was established. In the experimentation total twenty six clones were screened out from fourty nine planted rametes. In the plantation 3 m × 1.5 m spacing was maintained between clones. Parameters related to growth and physiology was noted annually. The result of the study stated that the clone C-188 found to be superior in maximum production of above and below ground biomass. In this study total five clones (C-188, C-186, C-19, C-10 and C-14) were screened out as producing of total higher biomass (Saravanan, 2019 A), whereas in case study of physiology following clones (C-188, C-186, C-14, C-10, C-123 and C-19) were found superior as high water use efficiency (Sarvanan, 2018). In case of better nutrient use efficiency following seven clones (C-188, C-10, C-14, C-19, C-123 and C-186) was observed superior and it leads to high biomass production and wood. (Sarvanan, 2019 B).

At the campus of Punjab Agriculture University a clonal trial was carried out to analyse the survival and growth performance of following nine Eucalyptus clones *viz.* (C-411, C-2045, C-413, PE-5, PE-11, PE-1, PE-7, PE-8 and PE-6) irrigated with effluent and planted in semi-arid conditions. Out of the nine clones eight clones were raised in the Mist Chamber and one clone (C-411) was procured from Prakriti clonal Agrotech. In this study nursery polybags were used and fill with silt and farmyard manure in the ratio of (1:1) and each clone of plant shifted in these polybags. Result of experimentation indicate the significant differences among the clones for the parameters of plant height and diameter at age of 4.5, 8 and 13 months. The clones C-413 and PE-5 performed better than other clones with respect to wood volume. The height growth of these clones (7.23 m and 6.60 m) was obtained relatively fast than other clone at the age of 13 months (Singh *et al.* 2020).

A clonal experimental trial of Eucalyptus was studied for adoptability and growth traits under seasonal water logging conditions in South-Western Punjab. In this experiment nine clones (C-413, C-3020, C-2135, C-7, C-2045, C-411, C-526, C-316 and seedlings) were planted and evaluate for adoptability and survival at farmer's field. Field layout was based on RBD design and three replication. Survival percentage of these clones- C-7, C-413, C-526 and C-316 were ranges from 78.3 to 88.3%. At the clones age of two and four year significantly difference was noted for plant height and diameter but volume index at four year age. Plant height at the age of four year ranges from 5.93 to 6.76 m, whereas DBH 56.4 to 87.6 mm. Volume index of following these clones were found to be superior in following sequence (C-413>C-316>C-411>C-7>C-526). The final conclusion of experiment revealed that clones- C-413, C-316, C-7 and C-526 were observed

as better adaptability and growth characters (Singh and Dhillon, 2020).

C. Plantation trial of Eucalyptus in India

In the Indian conditions total of 170 Eucalyptus species, varieties and provenances were tried to it gain the superiority of species. In this experimentation of plantation trial the Eucalyptus species *tereticornis* was found to be identical as growth and other qualitative parameters (Bhatia, 1984). It was also found that the species- tereticornis (*E. hubrid*) had better adoptability on wider range of soil conditions, faster growth, fire hardy under Indian subcontinent (Kushalappa, 1985). The result of other species *E. grandis, E. citriodora, E. globulus, and E. camaldulensis* were also noted best grown on plantation sites. In Indian conditions most of the forest lands are empty to forest tree plantations and low valuable. It may be a good approach to converting these lands to covering topography by valuable plantation by which we can increase the productivity of land and also generate the maximum government revenue from these virgin forest lands. Eucalyptus plantation may be good approach where sem problem is more due to highly irrigated areas and water logging condition. Plantation of Eucalyptus creates more opportunity to bridge the gap between demand and supply of Paper and pulpwood. Eucalyptus species mostly characterised as fast growing nature by which demand of pulpwood can be complete in short period of time and it also complete the wood fiber demand of industries by large scale plantation. It was found that plantation of Eucalyptus around the agricultural field lead in more competitive as both economically (R/C ratio: 16.6-12.4) and energy efficiency (213 to 295), study was carried out by Kumar *et al.* (2003). Eucalyptus plantation at the sites of eastern UP observed mixed plantation with agricultural field. Variation in growth performance of eucalyptus clones were assessed for screened out of superior ones for further multiplication and plantation at diverse edephic and climatic condition may lead to higher biomass and economic return (Lal *et al.* 2006).

An experimental trial was conducted on Eucalyptus based on micropropagation. In this experimentation two hybrids such as FRI-5 (*E. camaldulensis* × *E. tereticornis*) and FRI-14 (*E. torelliana* × *E. citriodora*) and nodal segments as explants was used. These explants and hybrid was established in MS medium supplemented with BAP and IBA/NAA. Result of experiment stated that rooting in MS medium supplemented with IBA noted superior and observed up to 92% rooting. Acclimatization and hardening of plantlets (90 - 98%) was also observed better at field conditions Arya *et al.* (2009).

Genetically improved planting material through clonal culture increased the productivity and profitability of forest plantations and attained up to 25 times higher yield as compared to naturally forest trees (Tahir Mushtaq *et al.* 2017). Forest Plantation programme also lead to correcting the vicious circle of low productivity and low incomes. In India many different types of state and centrally sponsored schemes are working to overcome the scarcity of pulpwood, paper, poles timber etc. Eucalyptus plantation is a good approach as farm forestry system at canal sites, on bunds of agricultural land.

An experiment was carried out at NRC for Agro-forestry, Jhansi to study the growth and yield of Eucalyptus clones under different agro-forestry systems. The mean annual increment in height (3.62 m) from boundary plantation, 3.27 m from agrisilviculture and 3.14 m from compact block plantation, respectively were noted from 4.5 years age of plantation, whereas dbh was observed as 3.88 cm from boundary plantation, 3.41 cm from agrisilviculture and 3.22 cm from compact block design. Non-linear models were attempted to fit height-dbh relationship. The allometric function results in reasonable estimation, even quite outside the observed range also, whereas other such as Richards and Schumacher leads to merely constant estimation for size in the extrapolated range. The conclusion of the experiment revealed that the allometric functions meet both, the criteria of high R2-value and reasonably acceptable extrapolated predictions was preferred over the other two models (Ajit *et al*. 2013).

A trial based on different spacing was carried out to assess the effect of spacing on growth and biomass production from plantation of *E. camaldulensis* species grown under arid climatic conditions at Tamil Nadu site. In the experimentation following different spacing for plant was followed *viz*, 3×3 m, 3×2 m, 3×1.8 m, 3×1.65 m, 3×1.5 m, 3×1.35 m and 3×1 m. The results of the study showed the significant effect of spacing on the growth and yield. The growth parameters noted significantly better from 3 × 3 m plant spacing and total utilizable biomass (72.72 kg/tree) was also follow the same trend of spacing, whereas maximum total volume per hectare was noted from 3×1 m spacing and minimum from 3×3 m spacing at different growth period. Maximum total biomass (113.59 ton/ha) was obtained also from the closer spacing of 3×1 m (Nagar *et al.* 2015).

A Eucalyptus plantation trial was conducted at dry land site of southern India. In the experimentation four provenances derived from 183 families, locally developed seed sources from 48 families and 10 clones of *E. camaldulences* species were evaluated for their survival and quality parameters. Analysis of data stated that the growing rate of naturally provenances and clones noted faster at 3 year of plantation. The natural provenances was also observed for high survival (72%) at same age and found to be better on local seed sources (67%) and clones (50%). In case of lignin content and basic density of wood none of the planting sources differed significantly, whereas clones noted for significantly maximum pulp yield. At the driest site wood density observed maximum (579 kg m^{-3}) but pulp yield noted minimum (Verghese *et al*. 2017).

A field trial was carried out at Haryana Agricultural University, Hisar, Haryana to identify best spacing with intercropping system to gain higher economic return. Experimental trial was based on three type of different

spacing as compact block (3m×3m), wider (6m×1.5m) and paired row (17m×1m×1m) was compared with sole Eucalyptus (3m×3m) and sole agriculture (without tree) cropping system. As the intercrop as kharif and Rabi-*Sesbania aculeata* and *Hordeum vulgare*, respectively were used with Eucalyptus plantation. As per the result analysis for economic return the spacing 17m×1m×1m was noted superior and gave maximum NPV (Rs. 185336) which was followed by 6m×1.5m spacing. In case study for B:C ratio the spacing 17m×1m×1m found to be superior and it ranges from 1:1.5. The final conclusion of this experimentation suggest superiority for economic return with paired row spacing (17m×1m×1m) (Dhillon *et al.*, 2018). A model based growth analysis study was carried out at ARS, Dharwad under rainfed condition. In this study five Eucalyptus species namely- *E. tereticornis, E. hybrid, E. grandis, E. pelleta and E. Dandeli* clones were evaluate with using of different growth models. Result showed that Gompertz growth model was observed as more suitable as compared to other ones to analysis of plant growth (Mahanta *et al.* 2019).

FUTURE SCOPE

Growing of genetically improved planting materials such as clones of eucalyptus not only improve the quality of product but also increase the productivity. It fulfils the demand of Eucalyptus based paper and pulp industries and meets the growing needs. The biotic and abiotic stress management programme may easily achieve through clonal plantation. By the clonal plantation with Eucalyptus farmers and industrial will get improved product in short period of time. Plantation of MLTs (Multi location trials) of eucalyptus at different regions will help to identify the superior ones as required in different climatic condition. Production of desired trait clones improves the vigour and adoptability of plantation. There is need to further improvement and introduced best quality trait germplasm which based on adoptability, low cost and future needs can be propagated on large scale. Collaborative research and careful prioritization of research projects will lead to reduction in costs and enhancement of benefits. Eucalyptus shows effective planning and implementation of afforestation programme for commercial plantation.

CONCLUSION

The final conclusion of review suggests that the clonal trial of Eucalyptus at different site produces superior clones as per need and performance will be helpful for the farmers to increase their livelihood. The areas where no water scarcity exists with soil and other parameters are good, clonal plantation of desired traits can give good biomass and ultimately better return.

REFERENCES

Aggarwal, P., and Chauhan, S. (2013). Longitudinal growth strains in five clones of *Eucalyptus tereticornis* Sm. *Journal of forestry research*, *24*(2): 339-343.

Ait-Ouazzou, A., Loran, S., and Bakkali, M. (2011). Chemical composition and antimicrobial activity of essential oils of *Thymus algeriensis*, *Eucalyptus globulus* and *Rosmarinus officinalis* from Morocco. *J Sci Food Agric*, *91*(14): 2643-2651.

Ajit, Dhyani, S.K., Handa, A.K., Chaturvedi, O.P., and Rajender, S. (2013). Statistical models for growth prediction in Eucalyptus under various tree based system. *International Journal of Agricultural and Statistical Sciences*, *9*(1): 261-272.

Arya, I.D., Sharma, S., and Arya, S. (2009). Micropropagation of superior Eucalyptus hybrids FRI-5 (*Eucalyptus camaldulensis* Dehn x *E. tereticornis* Sm) and FRI-14(*Eucalyptus torelliana* F.V. Muell x *E. citriodora* Hook): A commercial multiplication and field evaluation. *African Journal of Biotechnology*, *8*(21): 5718-5726.

Behera, L.K. (2016). Clonal variation in physical, anatomi-cal and chemical properties of wood of Eucalyptus. Ph.D. Thesis, Navsari Agricultural University, Navsari. pp. 215.

Behera, L.K., Jha, S.K., Gunaga, R.P., Nayak, D., Tandel, M.B., and Jadeja, D.B. (2017). Genetic variability and correlation study for growth characters among clones of Eucalyptus. *International Journal of Chemical Studies*, *5*(6): 763-765.

Behera, L.K., Patel, D.P., Gunaga, R.P., Mehta A.A., and Jadeja D.B. (2016). Clonal evaluation for early growth performance of Eucalyptus in South Gujarat, India *Journal of Applied and Natural Science*, *8*(4): 2066-2069.

Bhatia, C.L. (1984). Eucalyptus in India - its status and research needs, *Indian Forester*, *110*(2): 91-96.

Brooker, M.I.H. (2000). A new classification of the genus Eucalyptus. *Australian Systematic Botany*, **13**(1): 79-148.

Chevallier, A. (2001). Encyclopedia of medicinal plants. St. Leonards, New South Wales, Australia: DK publishing 2001.

Dhillon, G.P.S., and Singh, A. (2010). Variation in growth traits among progenies of *Eucalyptus tereticornis* Sm. under flood-plain conditions of Punjab. *Indian J. Agroforestry*, *12*(1): 91-94.

Dhillon, R.S., Chavan, S.B., Bangarwa, K.S., Bharadwaj, K.K., Kumari, S., and Sirohi, C. (2018). Eucalyptus-based agroforestry system under semi-arid condition in North-Western India: an economic analysis. *Indian Journal of Ecology*, *45*(3): 470-474.

Dhiman, R.C., and Gandhi, J.N. (2018). Growth performance and response of three biotic agents in commercially grown Eucalyptus clones in agroforestry. *Indian Journal of Agroforestry*, *20*(1): 16-22.

Gangwar, P., Pandey, V., and Tewari, B. (2015). Assessing productivity of Eucalyptus clones under different edaphic conditions. *Indian Journa of Research*, *4*(8): 43-44.

Huse, S.A., Gunaga, R.P., Sinha, S.K., Dobryal, M.J., Jha, S.K., and Bhatt, B.K. (2018). Genetic variation in growth attributes and pulp yield in Eucalypts clones. *International Journal of Chemical Studies*, *6*(4): 2903-2906.

Ilorkar, V.M., Kausadikar, P.H., and Khobragade, Y.R. (2016). Growth performance of different clones of *Eucalyptus tereticornis* under dryland conditions in Vidarbha region, Maharastra. *Journal of Tree Science*, *35*(1): 27-29.

Ishikawa, J., Shimotoyodome, Y., and Chen, S. (2012). Eucalyptus increases ceramide levels in keratinocytes and improves stratum corneum function. *International Journal of Cosmetic Science*, *34*(1): 17-22.

Joshi, I., Bisht P., SHARMA, V.K., and Uniyal, D.P. (2003). In vitro clonal propagation of mature eucalyptus F1 hybrid (*Eucalyptus tereticornis* × *E. grandis*). *Silvae Genetica*, *52*: 3-4.

Juergens, UR., Dethlefsen, U., Steinkam, G., Gillissen, A., Repges, R., and Vetter, H. (2003). Anti-inflammatory activity of 1, 8 - cineol (eucalyptol) in bronchial asthma: a double blind placebo-controlled trial. *Respiratory Medicine*, *97*(3): 250-256.

Juergens, U.R., Stober, M., and Vetter, H. (1998). Inhibition of cytokine production and arachidonic acid metabolism by eucalyptol (1.8-cineole) in human blood monocytes *in vitro*. *European Journal of Medical Research*, *3*(11): 508-10.

Kamalakannan, R., Varghese, M., Suraj, P.G., and Arutselvan, T. (2015). Options for converting a clone trial of *Eucalyptus camaldulensis* into a clonal seed orchard considering gain, fertility and effective clone number. *Journal of Forestry Research*, *24*(4): 4-10.

Kohli, R.K., Batish, D.R., and Singh, H.P. (1998). Eucalypt oils for the control of parthenium (*Parthenium hysterophorus* L.). *Crop Protection*, *17*(2): 119-122.

Kothiyal, V. (2014). Intra clonal variations of specific gravity and selected mechanical properties of *Eucalyptus tereticornis* Sm. *Journal of the Indian Academy of Wood Science*, *11*(2): 122-133.

Kulkarni, H.D. (2002). Bhadrachalam clones of eucalyptus-an achievement of ITC. Paper presented at the IUFRO science/policy interface task force regional meeting held in Chennai, India, 13-16 July.

Kulkarni, H.D. (2014). Industrial agroforestry: An ITC initiative. *Indian Farming*, *63*(11): 42-44.

Kumar, A., and Dhillon, G.P.S. (2016). Clonal testing of Eucalyptus clones and estimation of their genetic parameters. *Indian Forester*, *142*(2): 127-132.

Kumar, A., Luna, R.K., and Kumar, V. (2010 - B). Variability in growth characteristics for different genotypes of *Eucalyptus tereticornis* SM. *Journal of Forestry Research*, *21*(4): 487-491.

Kumar, A., Savita., Ginwal, H.S., Dobhal, S., Sharma, S., Shrivastava, P., Rana, A., and Kumar, R. (2017). Development and release of high yielding clone of *Eucalyptus Treticornis* SM. *Indian Forester*, *143*(12): 1221-1225.

Kumar, A., Sinha, A.K., and Singh, D. (2003). Studies of Eucalyptus plantations under the farm forestry and agroforestry systems of UP in Northern India. *Forests, Trees and Livelihoods*, *13*(4): 313-330.

Kumar, R., Bangarwa, K.S., and Desai, A.K. (2010 -A). Studies on evaluation of different *Eucalyptus tereticornis* Sm. clones. *Indian J. Agroforestry*, *12*(1): 49-52.

Kushalappa, K.A. (1985). Productivity and nutrient recycling in mysore gum plantations near Bangalore. Ph.D. thesis, Mysore University. pp 178.

Lal, P. (1993). Improving land productivity and returns from agroforestry plantations. *Indian Forester*, *119*(6): 431-440.

Lal, P. (2001). Private sector forestry research: a success story from India. *Bois et forets des tropiques*, *267*(1): 33-48.

Lal, P., Dogra, A.S., Sharma, S.C., and Chahal, G.B.S. (2006). Evaluation of different clones of Eucalyptus in Punjab. *Indian Forester*, *132*(11): 1383-1390.

Luna, R.K., and Singh, B. (2009). Estimates of genetic variability and correlation in Eucalyptus hybrid progeny for early selection. *Indian Forester*, *135*(2): 147-160.

Mahanta, D.J., Saikia, P., and Chetia, A. (2019). A study on the height growth of different Eucalyptus species in India. *The Journal of Analysis*, *27*(1): 293-310.

Nagar, B., Rawat, S., Rathiesh, P., and Sekar, I. (2015). Impact of initial spacing on growth and yield of *Eucalyptus camaldulensis* in arid region of India. *World Applied Sciences Journal*, *33*(8): 1362-1368.

Pant, R., Rai, A.K., Mathur, R.N., Sood, Y.V., Moorthy, R.S, Kulkarni, A.G., Kapoor, S.K., and Roy, T.K. (1980). Exploration and identification of alternative raw materials for paper and newsprint manufacture. Research report No. 22 and 23, Project IND/73/ 012.

Parul., Panigrahi, A., Jena, N.C., Tripathi, S., Tiwari, V., and Sharma, V. (2021). Eucalyptus: a review on agronomic and medicinal properties. *Biological Forum An International Journal*, *13*(1): 342-349.

Parveen, A., Kumar, V.K., Sharma. H.S., and Ginwal. (2010). Sustained hybrid vigor in F1 hybrids of *Eucalyptus torelliana* F.v. Muell x *E. citriodora* Hook. *World Applied Sciences Journal*, *11*(7): 830-834.

Saigal, S., and Kashyap, D. (2002). Review of company-farmer partnership for the supply of raw material to wood-based industry. Ecotech services, New Delhi, pp - 10-96.

Saravanan, S. (2018). Gas exchange characteristics and water use efficiency in Eucalyptus clones. *Journal of Stress Physiology & Biochemistry*, *14*(3): 49-58.

Saravanan, S. (2019 -A). Dry matter production in Eucalyptus clones. *International Journal of Agriculture, Environment and Biotechnology*, *12*(4): 381-387.

Saravanan, S. (2019-B). Nutrient use efficiency in Eucalyptus clones. *Journal of Stress Physiology & Biochemistry*, *15*(4): 5-14.

Silva, J., Abebe, W., Sousa, S.M., Duarte, V.G., Machado, M.I.L., and Matos, F.J.A. (2003). Analgesic and anti-inflammatory effects of essential oils of Eucalyptus. *Journal of Ethnopharmacology*, *89*(2-3): 277-283.

Singh, A. and Dhillon, G.P.S. (2020). Evaluation of Eucalyptus clones under seasonal waterlogging conditions in South-Western Punjab. *Curr Agri Res*, *8*(2).

Singh., A., Dhillon, G.P.S., and Dhillon, P.S. (2020). Survival and growth performance of Eucalyptus clones irrigated with effluents from liquor factory. *International Journal of Chemical Studies*, *8*(1): 2321-2324.

Singh, S.K., Kumar V., Jadeja, D.S., Jadeja, B.S., and Saxena, S.K. (2015). Morphological characterization of Eucalyptus clones for gall tolerance of South Gujarat. *India Plant Archives*, *15*(1): 607-614.

SriLakshmi, S., and Rao R.V. (2017). Clonal variation in selected wood anatomical properties and specific gravity of *Eucalyptus tereticornis* Sm. from two localities in Karnataka. *International. Journal of Fundamental and Applied Sciences*, *6*(1): 12-16.

Srivastav., Anubha., Anita, T., Yadav, A., Shukla, S.D., and Agrawal, Y. (2018). Early performance of Eucalyptus clones in Vindhyan region of Uttar Pradesh, India. *International Journal of Advance Research, Ideas and Innovations in Technology*, *4*(2): 549-552.

Tahir, Mushtaq., Banya, R., Mugloo, J., Mushtaq, T., and Aziz, M.A. (2017). Clonal forestry: an effective technique for increasing the productivity of plantations. *SKUAST Journal of Research*, *19*(1): 22-28.

Tiwari, K.M., and Mathur, R.S. (1983). Water consumption and nutrient uptake by Eucalyptus. *Indian Forester*, *109*(12): 851-860.

Ugalde, L., and Perez, O. (2001). Mean annual volume increment of selected industrial forest plantation species. Forest plantation thematic papers, working paper 1. Forest Resources Development Service, Forest Re-sources Division, FAO, Rome.

Vargese, M., Harwood, C.E., Hegde, R., and Ravi, N. (2008). Evaluation of provenances of *Eucalyptus camaldulensis* and clones of *E. camaldulensis* and *E. tereticornis* at contrasting sites in Southern India. *Silvae Genetica*, *57*(3): 170-179.

Varghese, M., Harwood, C.E., Bush, D.J., Baltunis, B., Kamalakannan, R., Suraj, P.G., Hegde, D., and Meder, R. (2017). Growth and wood properties of natural provenances, local seed sources and clones of *Eucalyptus camaldulensis* in Southern India: Implications for breeding and deployment. *New Forests*, *48*(1): 67-82.

Vennila, **S**., Parthiban, K.T., and Palanikumaran, B. (2017). Clonal evaluation of Eucalyptus genetic resources for pulping quality. *International Journal of Current Microbiology and Applied Sciences*, *6*(7): 4021-4031.

Vijayaraghavan, A., and Sivakumar, V. (2017). Selection of site-specific *Eucalyptus camaldulensis* and *Eucalyptus tereticornis* clones for Ariyalur region (Tamil Nadu) based on its higher Productivity IJRDO. *Journal of Biological Science*, *3*(2): 36-53.

Williams, L.R., Stockley, J.K., Yan, W., and Home, V.N. (1998). Essential oils with high antimicrobial activity for therapeutic use. *International Journal of Aromatherapy*, *8*(4): 30-39.

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