

## A REVIEW ON BIOMASS PRODUCTIVITY OF CASUARINA (*CASUARINA EQUISETIFOLIA* L.) THROUGH FERTILIZATION AND IRRIGATION APPROACHES

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**Abstract.** About 8.5% of the Earth's land surface area is potentially suitable for Casuarina growth and large-scale planting. However, in some climatically suitable areas, especially in countries like India large-scale invasions have not yet occurred, thus there is a substantial global Casuarina invasion debt. Due to policy developments tree cultivation outside forest area has become strongly promoted and Casuarina becomes one of the prominent tree species in coastal farmland cultivation. But the biomass and yield assessment of farm grown Casuarina is poorly understood. The challenge is to develop proper silviculture management approaches like fertigation scheduling and application that maximize the Casuarina yield in terms of productivity aspects. Fertigation is referred to a fertilizer application method that uses a drip irrigation system in which the fertilizer is dissolved in the irrigation water. However, many of the developments made in fertigation for agricultural sector is being adopted for tree crops, research on fertigation of trees is very much limited. The current paper review deals with the science of fertigation in forestry especially in Casuarina trees so as to meet the challenges of global fuel wood demand in the changing climate scenario.

**Keywords:** *water use efficiency, yield, validation, scheduling, plantation, fertigation*

## Introduction

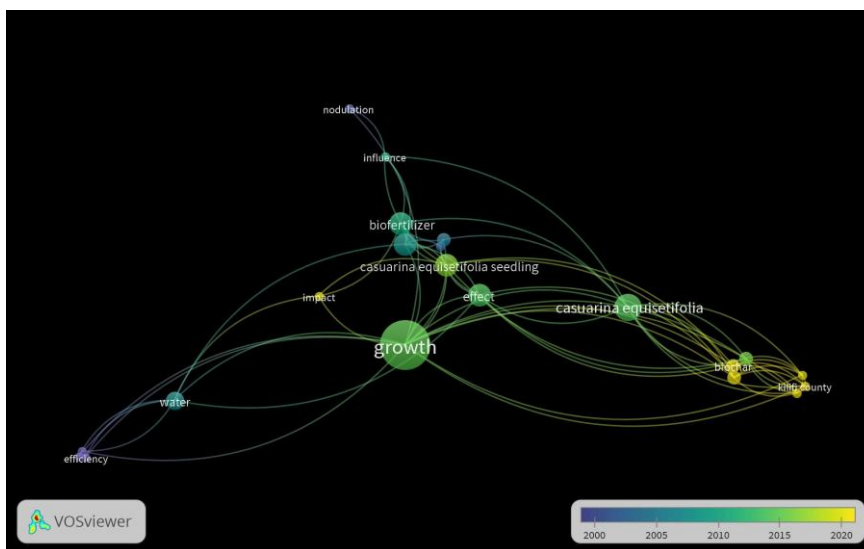
*Casuarina equisetifolia* L. commonly known as sheoak or ironwood, is a genus of evergreen trees and shrubs native to Australia, Southeast Asia, and the Indian subcontinent (Ribeiro-Barros et al., 2022; Berry and Shukla, 2023). These unique trees adapt well to a variety of environments, including coastal regions and arid zones, due to their ability to thrive in poor soil and withstand adverse weather conditions (Potgieter et al., 2014; Tiwari and Talreja, 2023). Casuarina is known for its distinctive jointed stems that resemble pine needles and its feathery foliage (Sayed, 2011).

In India, Casuarina plantations are actively promoted for their economic and environmental benefits. Casuarina is often grown in coastal areas to prevent soil erosion and protect against hurricanes (Tiwari and Talreja, 2023). Plantations also help to meet the demand for wood and firewood. Coastal states like Andhra Pradesh, Tamil Nadu and Odisha were actively involved in Casuarina cultivation. In terms of productivity, Casuarina is known for its fast growth and can thrive even in relatively poor soil conditions (Zhong et al., 2010), which makes it an attractive choice for afforestation and reforestation programmes. In India, factors such as age of plantation, soil quality and management practices influence the productivity of Casuarina plantations (Xue et al., 2016).

India is the largest Casuarina producing country in the world with approximately 800,000 hectares of plantations (Pinyopusarerk and Williams, 2000). Nicodemus (2014) estimates that about 500,000 hectares are under Casuarina cultivation in the coastal states of Andhra Pradesh, Orissa, Tamil Nadu and the Union Territory of Puducherry. Casuarina wood production varies greatly depending on location, cultivation techniques used and the age at which it is harvested. Plantations with irrigation and fertilizer application produce 100 to 150 tons of air-dried wood (up to 20 cm in circumference) per hectare (40 to 60 tons per acre) at 1 m x 1 m intervals for 4 years (Mutanal and Prabhakar, 2001). Under rainfed conditions, an average yield of 75 to 100 tons per hectare (30 to 40 tons per hectare) is achieved in 6 years, depending on the quality of the soil and the amount of rainfall during the growing season (Xiao et al., 2020). For each hectare, 5 to 7 tons of other wood is produced in the form of branches, tops and roots. At the time of harvest, the average height of the tree is 12 m and its girth is 25 cm. The best trees can reach a height of 20 m and a girth of 50 cm. The average net income from irrigated plantations is Rs 2,27,000 per hectare with a rotation period of four years. Under rainfed conditions, the same income is obtained in 6-7 years, depending on the type of soil and rainfall during the crop rotation period.

Fertilizers which are used in the fertigation system are generally water soluble fertilizers. These fertilizers are made of same chemical compounds as that of normal fertilizers but, the one thing is that they are absence of neutral insoluble materials such as gypsum, dolomite, clay etc. (Pahalvi et al., 2021). Therefore, these fertilizers are 100 per cent soluble in water without leaving any sediment in fertigation or clog the drip line (Papadopoulos, 1992). Irrigation and fertilization combined management is now widely used in the cultivation of all crop plants (Veeraputhiran, 1996; Vani and Bheemaiah, 2004; Tanpure et al., 2007) and trees all over the world. Many studies have suggested that using this approach water and fertilizer supplies are synchronised effectively (Veeraputhiran, 1996; Li et al., 2010), significantly increasing yield and water/nutrient use efficiency in crops (Shirazi et al., 2014) and trees (Da Silva et al., 2013). Fertilizers are often managed to optimize product quality in addition to maximizing yields (Zeng et al., 2017) and in trees it is a matter of wood quality (Sastry

et al., 1972). In order to attain normal growth and development in trees, each species require nutrients strictly in defined ratio (Sabo et al., 2019). This is accomplished by synchronizing fertilization rates and timing with the stage of growth. In forestry, especially in Casuarina species, the main goal of fertilization is to increase biomass production for wood volume and weight while avoiding serious quality degradation. The objective of the study is to evaluate how fertilization and irrigation techniques impact biomass productivity in Casuarina (Fig. 1), aiming to optimize growth conditions and enhance yield.



**Figure 1.** Interrelationship studies of Casuarina under fertilization and irrigation management (Source: VOSviewer)

### Importance of fertilization in forest plantations

In intensively managed forests, increased productivity has been achieved through improved resource availability by altering available water and nutrients (Coyle and Coleman, 2005; Laclau et al., 2024). Water scarcity limits nitrogen supply, but water abundance can also lead to nutritional losses through leaching in forest environments (Reid et al., 2024). The addition of nitrogen, on the other hand, is able to mitigate the harmful effects of water deficiency by increasing foliar nitrogen concentration (Yao et al., 2024) and photosynthesis, growth and root absorption, as well as water use efficiency (Alsafar and Al-hassan, 2009; Shirazi et al., 2014). Excessive application of water and fertilizer would not only increase costs, but also result in reduced water and fertilizer use efficiency and increased risk of nitrate pollution (Dong et al., 2011).

On the other hand, the main purpose of fertilization in forestry is to increase biomass production in volume and biomass without affecting its quality (Barros and Novais, 1996; Fife and Nambiar, 1997; Gonçalves et al., 2008). Fertilizers are also used on a small scale in forestry to control seed production (Williams et al., 2003) and disease occurrence (Ning et al., 2024). Excessive use of fertilizers in forestry results in multiple or twisted trunks, reducing the value of the tree for pulp or lumber (Turnbull et al., 1994; Gopalakrishnan et al., 2009), affecting wood density, diameter and length of fibers as well the angle depends on the microfibrils, thickness of the cell wall and lignin, cellulose and extractives are the main features of interest (Zobel, 1992; Downes et al.,

2002; Nyakuengama et al., 2002). Fertilization that increases conifer growth also reduces wood density but generally increases the overall value of the wood for lumber or pulpwood (Cao et al., 2008; Antony et al., 2009). Evaluate water and fertilizer application regimes. Therefore, it is necessary to increase productivity and resource efficiency by reducing the risk of pollution and waste accumulation in water resources (Alam et al., 2024) without compromising the quality of the beverage.

### **Irrigation in forest plantations**

A major reason for irrigated forest plantations is to attain increased yield (Guan et al., 2024). Good data as to the extent of irrigated forest plantations are not available (Bueno et al., 2020). The first major plantings began in 1864 in the Indus Valley and, by 1969, they represented 0.8-0.9% of the area under irrigation. In the Gezira irrigation project in the Sudan, represented 0.43% of the irrigated area in 1967. It is unlikely that irrigated plantations approach 1% of the overall area under irrigation in spite of sometimes extreme wood deficits (Armitage, 1985). Besides, widespread threats to forests resulting from drought stress are prompting a re-evaluation of priorities for water management on forest lands (Grant et al., 2013) with no doubt that forests and water are closely intertwined (NRC, 2008) not only for productivity but also for water conservation sustenance. Another compelling demand for irrigated forestry/ forest plantation is to increase yield and productivity of trees to attend the burgeoning demand of wood across the globe (Bainbridge, 2006). Which necessitated to push tree cultivation beyond the natural boundaries of forest, which is popularly attenuated as “trees outside forest” (Chauhan, 2006) And also offered great scope for commercial cultivation of trees both for economic benefits and environmental sustainability under that scenario of climate change (Auclair et al., 2000; Messaoud and Chen, 2011; Ellison et al., 2017). The resulting scarcity of fuel wood, timber for construction and wood for a huge array of industrial and commercial uses has imposed many developing countries (Zomer et al., 2006) to produce wood on-farm, either in woodlots or intercropped with other agricultural crops, has been promoted to meet rising demand with irrigated forestry/plantation (Puri and Nair, 2004). Among factors limiting productivity, water deficit is highlighted, which occurs in large cultivable areas, affecting plant-water relations and metabolism (Nogueira et al., 2000). The information regarding the water requirement of tree species is scarce (Bueno et al., 2020) which is an important component of tree cultivation. Several methods of irrigation are employed in plantations/trees depending upon age of the trees, topography of soil and availability of irrigation water (FAO, 1971). Most commonly adopted methods of irrigations are 1) Surface irrigation: Flood system, basin, boarder method, Furrow method etc. 2) Sub-surface irrigation: Drip irrigation 3) Overhead irrigation: Sprinkler irrigation. Many research evidences demonstrated positive effect of irrigation on growth and yield in trees like Hybrid Poplar (Ning et al., 2024), Eucalyptus (Lopes et al., 2007), Teak (Nayak et al., 2016), African Mahogany (Nayak et al., 2016), *Santalum album* (Mishra et al., 2018), *Dalbergia sissoo* (Kaleeswari and Balasubramanian, 2020), *Swietenia macrophylla* (Bhuva et al., 2020), and *Melia composita* (Jagani et al., 2020).

## Fertilizer application in *Casuarina*

Application of fertilizer is often limited to irrigated plantations and varies geographically and even within farmers. When fertilizers are administered between the months of June and July, when growth is at its highest, they will work best (Duhoux et al., 1996). One year after planting, farmers typically spray 50 kg of urea and 50 to 100 kg of Di-ammonium Phosphate (DAP) per acre (Jayaraj, 2010). In the third year, the amount is raised to 100 kg of urea and 100–150 kg of DAP. During the 6–12 and 18–24 months, 150 kg of DAP is applied per acre in Puducherry and coastal Tamil Nadu. Because *Casuarina* manufactures its own nitrogen with the aid of the bacteria *Frankia*, it does not require vast amounts of nitrogen fertilizer (Wheeler et al., 2011). Therefore, it is advised to apply 94 kg of super phosphate and 11 kg of urea at four different times: just after planting, six months later, and eighteen months later. If the ground is quite fertile, fertilizer treatment is not required after planting. DAP 100 kg per acre may be administered over a period of 12 to 24 months on low-nutrient soils (Parrotta, 1999). Fertilizers may be applied at the rate of 20-25 g nitrogen (N), 15-20 g Phosphorus pentoxide ( $P_2O_5$ ) and 15-20 g Potassium oxide ( $K_2O$ ) per seedling per year from the second year to the fifth year (Ravi et al., 2013). Further, growth hormones in *Casuarina* promote faster height and girth development, enhancing biomass production (Fig. 2).

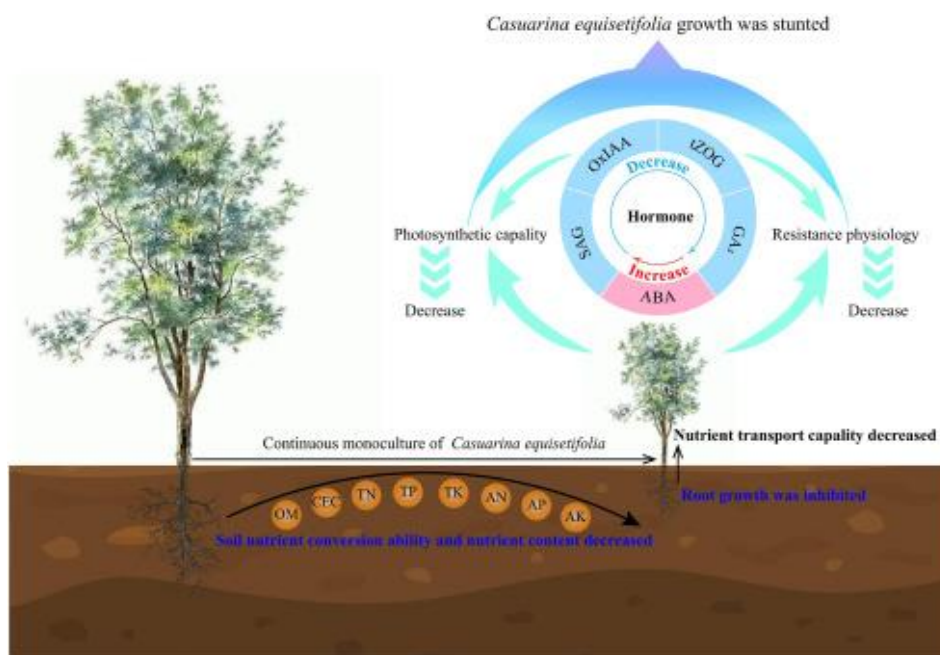


Figure 2. Effect of fertilization on *Casuarina* (Source: Wang et al., 2024)

## Silvicultural interventions under *Casuarina* plantation

*Casuarina* is very tolerant of many climatic conditions, it may be found in both coastal and dry places. *Casuarina* is an actinorhizal plant, which means it can fix nitrogen biologically (Ravi et al., 2013). As such, it grows most readily on sandy soils that are deficient in nitrogen and can help poor sites' nitrogen capital. Before the monsoon arrives, the site should be prepared by ploughing the ground two or three

times and digging trenches that measure 30 cm by 30 cm by 30 cm (Wheeler et al., 2011). Soil and Farm yard manure (FYM) are piled into the trenches. Following the first rain, planting is done right away. It is typical to plant in rows, blocks, and lines or strips. Different spacing is used based on the objective and end product (Duhoux et al., 1996). Usually a spacing of 75 cm x 75 cm is adopted. One or two weeding is done immediately after the rains. When the trees are about 3 m in height, the lateral branches are pruned to a height of about 2 m. Pruning is usually done at the end of the second year or after the beginning of the third year (Viswanath et al., 2020). In plantations established at close spacing (75 cm x 75 cm), one thinning in the second year or third year depending on tree growth is desirable, where 25-50 per cent of the trees are felled (Bhutia et al., 2024). In mixed species systems such as agroforestry, spacing and thinning practices are mainly dependent on the cropping systems and the nature of the associated species (Perez and Kanninen, 2005). If the associated crops are shade intolerant generally wider spacing and or intensive thinning are recommended.

### ***Fertilizer recommendation for Casuarina***

Fertilizer is applied in 10 split doses.

- The recommended dosage of fertilizer (RDF) for Casuarina is 200:200:300 gm of N: P: K / plant /year (Chaudhary et al., 2024).
- This dosage is applied throughout the year, except during the summer months of April – May (Yan et al., 2018).
- During the second year, the dosage is reduced and applied in the same way.
- In the following growth years fertilization is done only for alternative years (Rajendran and Devaraj, 2004).

### ***Fertilizer scheduling in Casuarina***

The practice of applying nutrients at the right rate, time and place according to the species can be termed as fertilizer scheduling (IPNI 2014). Fertiliser requirements (Assefa, 2014; Walshe, 2020) are affected by the type of soil (Srisuksai, 1991), previous cropping, the expected length of the growing season (Alzate et al., 2016) stand age (Santana et al., 2008), yield (Cheng and Raba, 2009) and nutrient demand of the tree (Silva and Rodríguez, 1995).

Fertilizer requirement in trees can be monitored by appearance of nutrient deficiency symptoms (Jani et al., 2021), soil analysis (Klinka et al., 1981), foliar analysis (Mahendrappa et al., 1986). The same fertilizer requirement can be monitored through mathematical models based on nutrient accumulation and released by fertilized trees (Miller, 1976) with the help of intelligent sensor systems (Lakhiar et al., 2018).

Nitrogen fertilization in boreal conifer forest at a recommended dose of 150 kg ha<sup>-1</sup> infers high timber yields and cash flows in spruce dominated stands growing on medium sites than pine stands (Pukkala, 2015) this is in contrary to Saarsalmi and Mälkönen (2001) where fertilizing pine trees were more profitable than spruce. Jordan et al. (2003), monitored N fertilizer uptake in Casuarina seedlings by 15N labelled fertilizer infers a reduced fertilizer uptake and growth owing to soil compaction while in *Quercus ilex* under favourable nursery conditions increasing rate of fertilizer 200 mg N plant<sup>-1</sup> increased more nutrient uptake and biomass of the seedlings (Oliet et al., 2009). In Casuarina plantations, trees respond positively to the increasing rate of fertilizers (four fold dose of 40 kg ha<sup>-1</sup> N; 16 kg ha<sup>-1</sup> P; 53 kg ha<sup>-1</sup> K) at the initial stages however

the effect goes on decreasing in subsequent years (Silva et al., 2012) as the tree response to fertilizer doses generally diminishes with tree age (Santana et al., 2008) while a split application of fertilizer at rates of 125 and 250 g (16N–7P–7K) per seedling increased growth and biomass accumulation in *Casuarina* clones (Zeng et al., 2013). Fertilizer dose of 50 N: 25 P<sub>2</sub>O<sub>5</sub>:50 K<sub>2</sub>O kg ha<sup>-1</sup> year shows an increment in mean height and diameter while dose of 100 N: 50 P<sub>2</sub>O<sub>5</sub>:50 K<sub>2</sub>O kg ha<sup>-1</sup> showed an increase in crown width in *Ailanthus triphysa* saplings under an agroforestry system but the observations were not significant (Kumar et al., 2001). In *Casuarina* clones dual inoculation of biofertilizers, Rhizobium and Arbuscular Mycorrhizal (AM fungi) results in an increasing growth and biomass under normal soil while in alkaline soil blending of micronutrients with dual dose of biofertilizers inferred a favourable outcome (Revathi et al., 2013). The application of 163 kg ha<sup>-1</sup> urea, 375 kg ha<sup>-1</sup> mussoorie rock phosphate, 145 kg ha<sup>-1</sup> muriate of potash, 105 kg ha<sup>-1</sup> quick lime and 373 kg ha<sup>-1</sup> Mg sulphate from two split applications in the first year and four split applications during the second and third years in young plantations of *Casuarina equisetifolia* in Tamil Nadu (Figure 3) was recommended by Balagopalan et al. (2000), cited in Kumar (2011), while in Costa Rica application of N-P-K at the rate of 10-30-10 or 12-24-12 at the beginning of the rainy season and an extra N dose during the maximum rainy days up to 3 to 4 years is practiced (Alvarado, 2012).



**Figure 3.** *Casuarina* under drip irrigation system (Age: 3 Months)

### **Effect of fertilization and irrigation on biomass productivity of *Casuarina***

Fertilization and Irrigation both plays a significant impact on tree growth and biomass production (Song et al., 2015) by synchronising the application of water and nutrients (Morgan, 1984) and hence significantly increasing the yield and improving the water and nutrients use efficiency while achieving sustainable use of water and nutrients (Yohannes and Tadesse, 1998; Shirazi et al., 2014). Extensive studies on fertigation in forest trees are limited and some of the research evidences related to tree fertigation is discussed. The drip irrigation and fertigation treatment in *Casuarina* clonal plantation showed incremental effect on height than diameter and the increment percent of basal area, height and stem volume was about 28, 44 and 57% respectively which were higher than control (Song et al., 2015). The N fertigation in *Casuarina equisetifolia* influenced

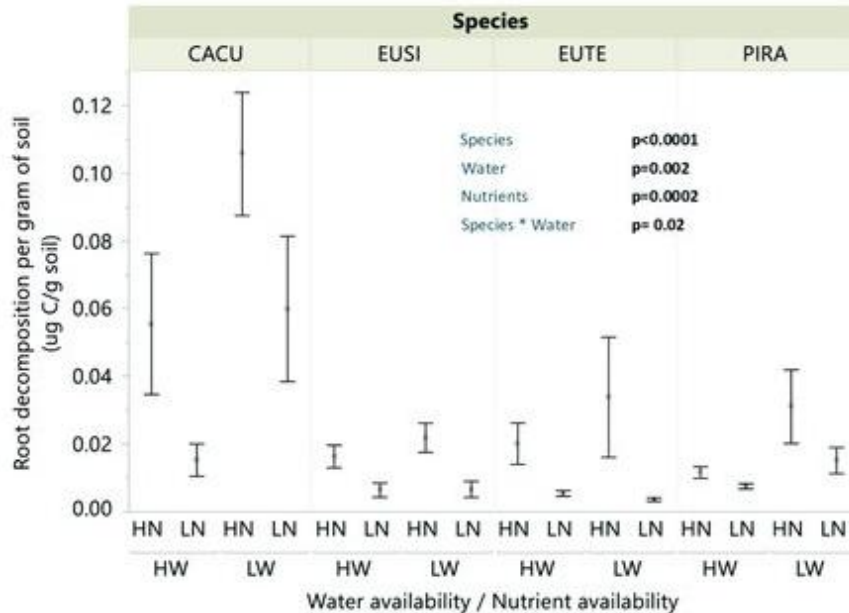
basal area and the above ground diameter by 38% (N115), 30% (N230) and 32% (N345) (Wang et al., 2015). The estimation of above and below ground biomass in sweet gum (*Liquidambar styraciflua* L.) and She-oak (*Casuarina equisetifolia*) plantation which is under proper irrigation and fertilization by Coyle et al. (2008) showed increase in mean annual aboveground biomass for sweet gum ranged from 2.4 to 5 Mg ha<sup>-1</sup>yr<sup>-1</sup> and for She-oak it ranged from 5 – 6.9 Mg ha<sup>-1</sup>yr<sup>-1</sup>. Another examination by Liza et al. (2014) in She-oak (*Casuarina equisetifolia*) with respect to fertigation recorded the maximum basal area and stem biomass were 41 m<sup>2</sup> ha<sup>-1</sup> and 172 Mg ha<sup>-1</sup>, respectively. The study also inferred that fertigation increased foliar nitrogen concentration and foliage biomass. The trial conducted for 12 years by fertilizing with balanced amount of macro and micro nutrients applied to the stands of Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abis* L.), concluded that there was a large increase in the stem wood production after the treatment (Axelsson and Axelssoni, 1986). Fertilization demonstrated that there is a significant increase in stem wood production per unit of foliage in the first five years of fertilization in both the pine and spruce experiments. The water stress experiment conducted in scats pine evolved that a drought would increase root growth while comparing with shoot growth. The research on effect of irrigation and chemical fertilizer on growth and productivity of *Casuarina equisetifolia* in Punjab (India) concluded the impact of the interaction between the fertilizer doses and irrigation were statistically significant which was contrary to investigation of Vani and Bheemaiah (2004) where they found no interaction effect. A field trail on productivity of teak (*Tectona grandis* L.) under fertigation on medium black soil, with three fertilizer levels and five fertigation frequencies under drip irrigated system concluded that there was an increase in height, diameter at breast height, basal area, and volume, for fertigation application in six splits a year and there was an increase in the volume for the fertilizer doses at 200, 43, and 166 kg, and 300, 64.5, and 249 kg N, P, and K / ha (Mutanal and Prabhakar, 2001).

### Water use efficiency of Casuarina

Water use efficiency (WUE) is explained as the amount of carbon assimilated as biomass or grain produced per unit of water used by the crop (Hatfield and Dold, 2019). Water use efficiency (WUE) is a concept introduced 100 years ago by Briggs and Shantz (1913) showing a relationship between plant productivity and water use. Water use efficiency is a key indicator of the carbon sequestration potential (Baldocchi, 1994). Tree carbon dynamics and water cycling are tightly coupled as plant balance carbon against water loss through the regulation of stomatal conductance (Whitehead, 1998). The rate of carbon gain per unit of water loss is known as WUE has been widely recognized as an important physiological link between carbon and water cycling (Zhu et al., 2011). Effective irrigation can enhance WUE by providing water at critical growth stages, maximizing biomass without excessive water use (El-ghait et al., 2022). Fertilizer application, particularly nitrogen, can improve WUE by promoting root development, enhancing nutrient uptake, and boosting growth rates (Fig. 4). *C. equisetifolia* shows adaptive mechanisms like reduced stomatal conductance in water-scarce conditions, which help maintain WUE by limiting water loss while still supporting growth (Yadav et al., 2023).

Requires no watering once established. Generally, trees need supplemental irrigation to get established, especially if planted after the rainy season. During the first year,

irrigate in the amount of 20 – 25 liters of water twice a week. During its second year, a tree needs to be irrigated in the amount of 40 liters once a week (Hopmans et al., 1990). Beginning with the third year, trees usually get established, and some, like the Australian Pine, do not require any supplemental irrigation.



**Figure 4.** Nutrient availability and root decomposition of Casuarina (Source: Carrillo et al., 2022)

### Spatio temporal changes of yield with respect to fertilization and irrigation

Linear multiple regression method was used to model the relationship between the dependent and independent variable (Whittaker and Woodwell, 1968). The parameters namely age, total height and mid diameter of the Casuarina tree were defined as the independent variables and total volume as dependent variable (Williams and Schreuder, 2000). The general equation developed through the linear multiple regressions was

$$Y = a + b_1x_1 + b_2x_2 + b_3x_3 + \dots + b_nx_n \quad (\text{Eq.1})$$

where,

Y – Yield (m<sup>3</sup>),

a – intercept,

x<sub>1</sub> – age of the tree in years,

x<sub>2</sub> – Mid Diameter,

x<sub>3</sub> – Height of trees,

b<sub>1</sub>, b<sub>2</sub>, b<sub>3</sub> – Coefficients of b<sub>1</sub> and b<sub>2</sub>.

In Casuarina plantations of Tamil Nadu and Costa Rica, yield model was constructed and best fitted with each Casuarina plantation and they confirmed that best-fit models developed for one plantation or zone cannot be used for other plantations or zones (Eq.1). This study also proved by Balasubramanian (2019) that the power equations proved to be far more superior to other equations as evidently shown from its greater

values of coefficient of determination ( $COD = r^2$ ) as well as from lesser values of standard error (SE). The yield model was developed for *Casuarina equisetifolia* in Ghana with the equation of  $\ln(V) = 8.3023 + 2.1746 \ln(V)$  and  $\ln(D) = -9.1864 + 1.85502 \ln(H) + 0.8234 \ln(D)$  were found to be best fitted models for She-oak tree grown in forest plantations of Ghana. Biomass estimation studies by Pérez-Cordero and Kanninen (2003) and Morataya et al. (1999), in Costa Rica reported that, variables such as diameter at breast height (DBH) and total height alone utilised for framing linear and logarithmic equations as the best-fit models.

### ***Validation of yield models***

Yield models are mathematical functions relating growth/yield to site index, stand age, and some measure of stand density. Sullivan and Clutter (1972) constructed the basic form of growth model for predicting volume of standing trees. The model relates yield/growth in terms of volume per hectare site index and stand age. This yield model has proved to be useful, reliable and widely used for many pure even-aged forest stands and even aged plantations (Vanclay, 1994).

The developed yield models were validated using the residual plot analysis technique (Alder and Synnott, 1992). A set of biometric data, observed from the study area were selected for the validation. Biometric data selected for the validation is not used in the yield model development. Actual volume of the selected biometric data was computed using the above methodology and further the developed model was used to compute the predicted volume. The actual volume and predicted volume of the same data were regressed to validate the model. The smaller the residual sum of square values obtained, developed model is closer to the original data.

Chi-square test for goodness fit was conducted to study the consistency of the developed yield model. The yield model developed will be assumed to fit for all independent data, if the p value obtained in this test was larger than the significance value (0.01).

### ***Fertigation versus conventional fertilization***

Global fertilizer demand is predicted to increase significantly to 202 million Mg in 2020 and the demand for basic nutrients (nitrogen, phosphorus and potassium) will increase on average by 1.5, 2.2 and 2.4% from 2015 to 2020 annually (FAOSTAT, 2020). Fertigation method confirms the saving in fertilizer usage (Deshmukh et al., 1996), facilitates supply of nutrients near to the root zone (Chojnacka et al., 2020) and the migration of nutrients to the deeper layers of soil or groundwater decreases (Incrocci et al., 2017). Hence, the frequent application of water, optimum split applications of fertilizer ensures an increase in quality and quantity of yield than the conventional method (Ramniwas et al., 2013; Ebrahimian et al., 2014; García-Gaytan et al., 2018). The use of fertigation decreases the need for fertilizer and water (up to 25%) (Lv et al., 2019) and in drip irrigation systems there was water savings of 40–60% than basin irrigation methods (Orlofsky et al., 2015). Tree crops are being promoted for commercial cultivation has no doubt require efficient fertigation system as part of the silvicultural management of especially for manmade plantations to meet the sharp increase of wood demand across the globe.

## Conclusion

The increasing demand coupled with vast deforestation of forest necessitates promoting tree outside forest for commercial production and wood products. At this changing scenario of tree cultivation systematic introduction of silvicultural management techniques like fertilization and irrigation combined as fertigation is an important tool for maximizing productivity both in natural and manmade forest environment. Although, the tree fertigation is not a well-developed science but greater scope exist for developing species and site selection techniques for greater scope. Nutrient and water use efficiency are of important criteria for scheduling combined effect of water with fertilizer in addition to tree cultivation is consider to promote under waste land and arid condition with the help of waste water which are otherwise not presently utilized fully. As a whole fertigation in trees especially in fast growing trees like Casuarina is being consider as an important component for growth productivity, carbon sequestration, climate change mitigation without compromising economic development across the globe by means of tree cultivation. The challenges in fertigation for tree cultivation requires fertigation scheduling, fixing doses of fertilizers, promotion of Casuarina cultivation in waste lands and arid lands and judicious use of waste water for tree cultivation.

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